PUBLISHED BY THE INSTITUTE OF FOOD TECHNOLOGISTS

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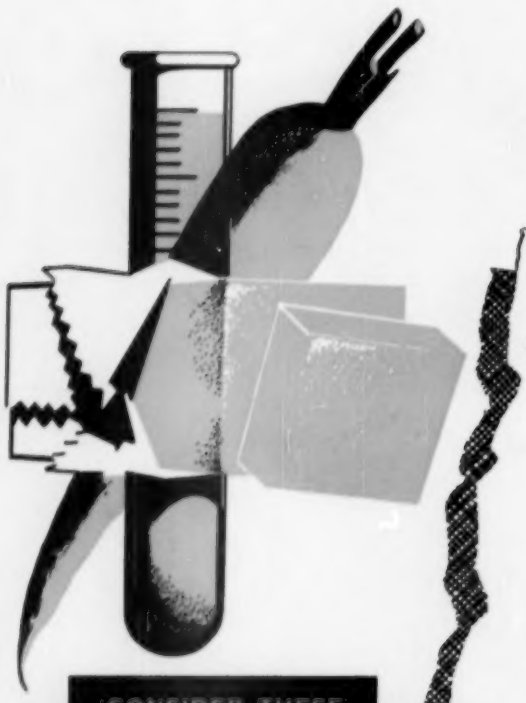
BARNETT'S Carotene is *Natural* Carotene



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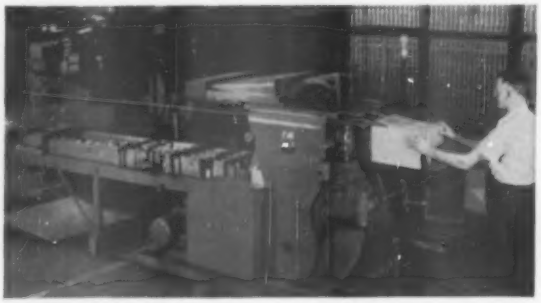

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2. Cut handling costs and manpower
3. Provide smooth, uniform handling
4. Eliminate can and product damage

These are a few of the many ways you save with FMC Can Handling Equipment—savings that help build bigger profits for you! And once you've installed this equipment, you're in for the added benefits of low operating and maintenance costs through years of continuous service.

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(This advertisement originally appeared in full-color in TIME, BUSINESS WEEK and FORTUNE.)

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Plastic Bottles
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Vynite Tubes
Bondware®
Plastic Pipe

The Vital Story of VITAMIN A

by Science Writer

We live in a golden age of the sciences!

In the science of nutrition discoveries of food elements and their action have resulted in the promise of better health for us all.

Let's consider vitamin A as an example.

A Capsule History. 1913 was the year. Two teams working independently with animal feeding experiments discovered that a diet which was good in all other respects but which varied only in the source of fat caused young animals to thrive or sicken as the fat was varied. The work of these teams (McCollum and Davis; Osborne and Mendel) led to the discovery of the food factor which we know as vitamin A.

Composition and Action. A pale yellow, oil-soluble substance, vitamin A is expressed in the chemist's shorthand as $C_{20}H_{29}OH$. It is necessary in the diets of men and animals to promote the body's growth and development. Vitamin A is a vital requirement in guarding the health of the eyes and skin, and for resistance against infection. It helps maintain the health of mucous membranes and other specialized epithelial and glandular tissues.

Vitamin A enters the body as a constituent of food. Or it may be created within the body when a precursor of vitamin A is eaten. A precursor is a food element with potential vitamin A *value* but no actual vitamin A *content*. For instance, many green leaves have a high vitamin A value but, paradoxically, contain no actual vitamin A. The body converts the precursor into the vitamin. The most common precursor of vitamin A is beta carotene, the natural yellow coloring of many foods, such as dairy products, cereal grains, carrots, alfalfa, etc.

When consumed in food vitamin A is absorbed primarily in the healthy intestine, is esterified in the intestine's walls and is carried as an ester in the lymph and blood to the body's storage depots. The liver, which has a large capacity for storage, contains about 90% of the vitamin A found in the body.

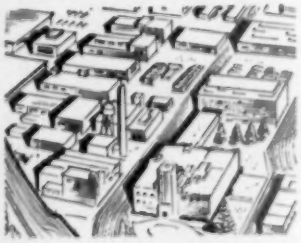
Isolation and Synthesis. It was not until 1937 that pure, crystalline vitamin A was isolated by Holmes and Corbett from fish-liver oil. Research in the synthesis of vitamin A was stimulated during the Second World War by the threat to natural sources in fish-liver oil. This work resulted in several processes to produce vitamin A synthetically. Of these, one of the most successful was evolved by the Roche research team headed by Dr. Otto Isler which was announced in 1947. Much of the vitamin A now used for pharmaceutical manufacturing and food fortification in the United States and many other countries of the world is produced by this process.

Vitamin A and beta carotene produced by the Hoffmann-La Roche synthesis have many positive advantages for food and pharmaceutical manufacturers. Among these are the complete absence of any "fishy" odor, taste, or after-taste; the reasonable and stable price; their stability, purity and uniformity and the assurance of a steady economical supply.

Vitamin A is described in the U. S. Pharmacopoeia as a fully acceptable compound for use in pharmaceutical products. The U. S. Food and Drug Administration has approved its use for the fortification of margarine and other foods.

Human Requirements. The Food & Nutrition Board of the National Research Council recommends that a daily allowance of 5000 International Units of vitamin A in the diet will maintain good nutrition of healthy adults in the U.S.A. The Board's recommendations vary above this for pregnant and lactating women, and below for infants and children. The adult dose used in therapy may vary from 50,000 to 200,000 units daily.

Production. At the huge Roche Park plant of Hoffmann-La Roche in Nutley, New Jersey, over 500 pieces of large-scale chemical engineering equipment are working constantly to produce the superior 'Roche' vitamin A. This production is so large that 'Roche' vitamin A comes from the plant actually by the tons. In fact, the entire needs of the food and pharmaceutical industries of the United States and Canada can be met from this one plant.



Again the Roche people, who have so often led the way in vitamin research and production, have made another contribution to the better health and well-being of countless millions.

This article is one of a series giving a brief resume of our present knowledge of those essential health factors—the vitamins. Reprints of this and other articles are available without charge. The Vital Story of Vitamin C was published previously and others are forthcoming. Send your request to: Vitamin Division, Hoffmann-La Roche Inc., Nutley 10, New Jersey. In Canada: Hoffmann-La Roche Ltd., 286 St. Paul St., W.; Montreal, Quebec.

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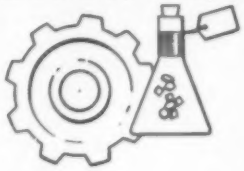

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NUMBER 8

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Affairs of the Institute

Regional News
Announcement of General Foods Fund Inc. Fellowships, 1956-57
Announcement of Florasynth Award, 1956-57
Selected Abstracts
Books
Recently Elected Members
Food Industry Topics
Future Meetings

Regional Section News

INDIANA SECTION

The Indiana Section, IFT, has elected officers for the year 1955-1956, as follows:

Dr. Stanley E. Hartsell—Chairman
Dept. of Biological Sciences, Purdue University, Lafayette, Indiana

Mr. Alfred P. Rumminger—Chairman-Elect
6102 East 21st Street, Indianapolis, Indiana

Miss Verna McCallum—Secretary-Treasurer
Stokely-Van Camp, Inc., 941 N. Meridian St., Indianapolis 6, Ind.

Dr. Norman W. Desrosier—Councilor
Dept. of Horticulture, Purdue University, Lafayette, Indiana

MOHAWK VALLEY SECTION

On March 17, Mr. Ray Woodford, Head Chemist at Arkell & Smith, paper bag manufacturers, spoke before the Section members on the origin, history and modern technology in the paper bag industry.

At the May meeting, Mr. John Nohe of the McCormick Spice Company, outlined the history of spices and discussed current processing methods and present-day procurement problems.

Our guest speaker for the June meeting was Mr. George Schmidt of Fritzsche Brothers, Inc. who presented color movies taken by Dr. Ernest Guenther, Head Research Chemist for Fritzsche Brothers, concerning the production of citrus oils and essential oils in the Western Hemisphere, Africa and the Far East.

On July 14, the annual family picnic was held at Wintergreen Park in Canajoharie, N. Y. Over fifty adults and children enjoyed the food and informal sports activities.

NORTHEAST SECTION

The 1955-56 season of the Northeast section opened on October 6th, at the Smith House in Cambridge, Mass. with a splendid talk by Dr. Henry B. Hass, President of the Sugar Research Foundation who spoke on recent developments in Sucro-chemistry. A crowd of over one hundred persons attended, and Dr. Hass' talk well lived up to expectations.

The opening of this season also saw the appearance of "The Nor'Easter," a new face for the section's monthly newsletter, which is aimed at providing more complete news coverage for all section members.

Among the items of importance in Vol. I, Number 1, is the resignation of the chairman, Dr. Ernest E. Lockhart, who is transferring to the New York area, and the advancement of Mr. W. Leverett Cummings from vice-chairman to chairman. Dr. Samuel A. Goldblith, who held the office of national councillor, was appointed as vice chairman. Dr. Jean F. Caul, the most recent past chairman was appointed national councillor.

The committee chairmen appointed by Mr. Cummings are:

Auditing: Lee Shipman
Budget: Arthur S. Levine
Employment: William P. Hinckley
Hospitality: Laurence Spiegel and Charles Bates
Membership: Richard A. Minard
Nominating: Samuel C. Prescott
Prescott award: Jean F. Caul
Program: Samuel A. Goldblith

At the recent meetings of the Section's executive committee it was voted to turn over the funds being held for the Prescott award to the National Organization and with it the administration of the award. It is hoped that it will be accepted at the next National Executive Committee Meeting and that IFT as a whole will attempt to obtain sufficient endowment to establish this award on a basis worthy of the prestige and dignity of North-East's own beloved Dean Prescott.

SOUTHERN CALIFORNIA SECTION

September meeting. We SCIFTERS started the season by awarding our certificate of appreciation for "outstanding contribution to the science, technology and advancement of the food industry" to Mr. Roy M. Hagen, long active in the work of this Section. Mr.

Hagen (left) receives award from Chairman Lindquist.

Hagen is a graduate of the University of California and a former assistant professor in the College of Agriculture at Berkeley. He was successively secretary-manager of the California Cattlemen's Assn., general manager of the Sunmaid Raisin Growers, and president and general manager of the California Consumers Corp., which post he holds today. In addition to business, Mr. Hagen has been active in civic affairs. He was chairman of the Agricultural Committee of the Los Angeles Chamber of Commerce from 1947 to 1950, and in 1953 was chosen president of the Chamber itself, resigning as treasurer of our section of IFT in order to take this post. In 1954 he was made chairman of the Metropolitan Traffic and Transit Committee of the Los Angeles Chamber of Commerce.

The California Consumers Corp. (which Mr. Hagen joined in 1931) had miles of refrigeration pipe-lines in use when the home refrigeration boom got under way. To paraphrase an old proverb, "It's a rare wind that

(Continued on page 8)

THINGS TO COME...WITH

Glycerine

for fruit and vegetable growers..

NEW HELP ON BACTERIAL BLIGHT

Recent greenhouse studies by scientists at Merck & Co. Inc., show that addition of Glycerine to streptomycin sprays increases the effect of the antibiotic against bacterial blight of beans, a disease which costs farmers millions of dollars each year.

Researchers believe the increased effectiveness of the combined spray comes from Glycerine's ability to retain moisture on leaves, and in so doing, to improve absorption of streptomycin by the plant.

Indications are that the Glycerine-streptomycin combination will also help control other disease-causing organisms which infect leaves, flowers and stems of various fruits and vegetables.

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REGIONAL SECTION NEWS

(Continued from page 6)

blows nobody any ill" and this refrigeration boom was being lowered on the California Consumers Corp. Mr. Hagen decided to get into a business that was growing —the frozen food field. His company is now a large producer of high quality frozen foods.

Mr. Hagen, speaking on his activities as president of the Los Angeles Chamber of Commerce, said he wanted Los Angeles to be the most friendly community in the United States. He discussed eight big problems which the city faces and the objectives which in time will solve them—four relating to business development, and four for community benefit. For business, these are the objectives:

(1) Make L. A. the air center of the U. S. Mr. Hagen succeeded in getting a franchise for a Swedish air-line, for which he was knighted by the King of Sweden.

(2) Add 100,000 industrial jobs.

(3) Find sales for $40,000,000 more goods.

(4) Make L. A. the industrial research center of the U. S.

For community welfare, these are the goals:

(1) Solve the traffic problem, emphasizing the building of freeways.

(2) Solve the water problem; Mr. Hagen believes that California, Arizona and New Mexico can settle their differences with or without the Congress of the U. S.

(3) Eliminate the smog; he recommends car pools, reducing back-yard incinerators, and encouraging "smog" industries to consider relocating.

(4) Improve sewage disposal; sooner or later he believes we will have to build more sewers.

Mr. Hagen concluded by saying that the thing that made him happiest in his year as president of the Chamber of Commerce was that of the hundreds of people he had asked to do one thing or another, only one man had refused to comply.

WESTERN NEW YORK SECTION

Mr. John Link, Assistant Erie County Agriculture Agent, addressed the first meeting of the Fall Session of the Niagara Frontier Division of this Section. Well informed on conditions and problems of the farmer, he explained some of the effects of the past and present weather conditions on the current crops, and also a view of the long-range planning on crops. The meeting was held at the Hotel Westbrook, Buffalo, on September 26.

WESTERN NEW YORK SECTION

The Section held its 1955 Fall Meeting on October 7 in the Lafayette Hotel in Buffalo, N. Y. The morning was devoted to visiting the Research Laboratories of National Aniline Division of Allied Chemical & Dye Corp. Dr. L. E. Clifcorn, IFT President, guest speaker at the Luncheon, spoke on "The Problem-Chemicals in Foods." The afternoon session heard the following papers:

"The Addition of Flavors to Foods." Mr. Arthur Downey, Assistant Vice President and Director of Research, Magnus, Mabee and Reynard, New York City.

"Pigments in Sour Cherries." Dr. A. C. Wagenknecht, New York State Agricultural Experiment Station, Geneva, N. Y. (Dr. Wagenknecht was recently named winner of the Gerber Post-doctorate Fellowship.)

"Industries in Our Area."
(1) Loblaw Inc., Mr. Paul W. Hodler, Buffalo
(2) Maple Leaf Milling Co., Dr. Ralph K. Larmour, Toronto
(3) Best Foods Inc., Dr. Edwin L. Sexton, Buffalo.

"Toxicity Testing; Techniques and Methods of Evaluation. Dr. Aaron Arnold, Sterwin Chemicals Inc., New York City.

On October 10 the Section met jointly with the American Association of Cereal Chemists in the Erie County Institute. Frank Schwain, who has been in charge of bakery research since 1947 at Procter and Gamble of Cincinnati, Ohio, presented an illustrated talk on "Cake Quality as Influenced by Temperature Control."

TEXAS SECTION

The Texas Section, Institute of Food Technologists, held a meeting at 4:00 P.M., October 1, 1955 at the Memorial Student Center, Texas A & M College, College Station, Texas. After a short business meeting, Dr. Robert E. Branson delivered a paper on the subject of Measurement of Consumer Preferences in Foods. His paper covered work and experiences in this field with respect to such varied materials as citrus products, prunes, chicken and beef. After this talk the group went to the meats laboratory where a delicious barbeque dinner was served. Following the dinner the group enjoyed the football game between the Texas Aggies and the University of Houston.

PERSONNEL

At the University of Massachusetts, Dr. E. E. Anderson has been promoted to Associate Research Professor of Food Technology; Dr. F. John Francis has been appointed an Assistant Professor of Food Technology.

At the Massachusetts Institute of Technology, Dr. John T. R. Nickerson has been promoted to the rank of Associate Professor of Food Processing and Dr. Samuel A. Goldblith has been promoted to Associate Professor of Food Technology and appointed Executive Officer of the Department of Food Technology.

Mr. Dominick Frank has been named Director of Sanitation of Pacific Gamble Robinson Co., Minneapolis, Minnesota, fruit and vegetable wholesalers. Mr. Frank was formerly with Rockwood and Co., Brooklyn, New York, cocoa manufacturers.

Dr. Arthur N. Prater has been appointed executive vice president of Gentry, a division of Consolidated Foods Corporation, according to an announcement by George E. Clausen, Gentry president. Dr. Prater, who has been with Gentry for 11 years, has held important posts both in research and administrative phases of the Company's work. He comes to his present appointment after a year as vice president in charge of production.

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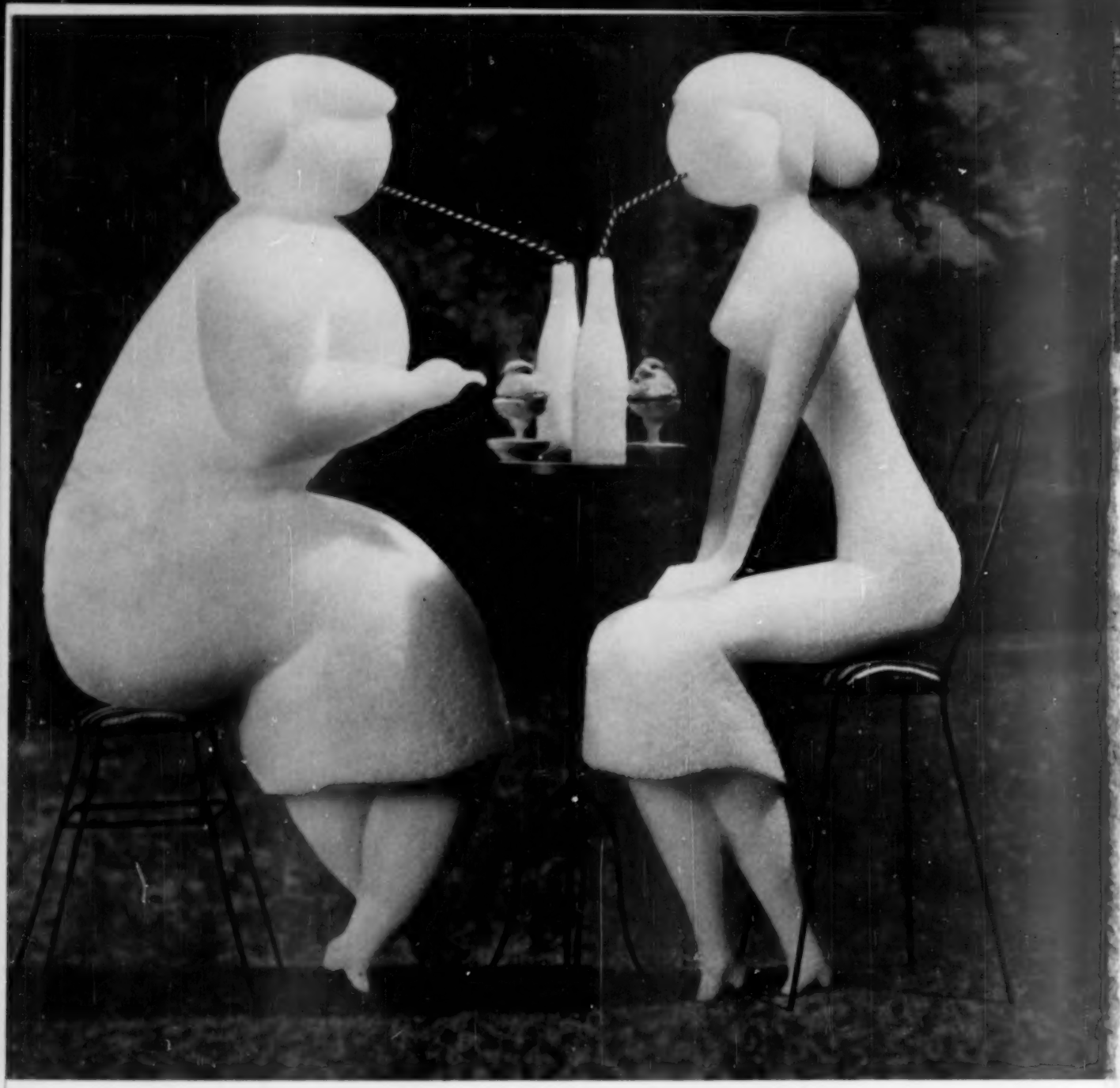

You add a BIG customer...when you add a **Sucaryl**® sweetened line

The big attraction of calorie-free Sucaryl is that it tastes just like sugar, with no bitter aftertaste.

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Florasynth Fellowship Award for 1956-1957 Open for Competition

Provided by the Florasynth Laboratories Inc., New York, N. Y., and given annually to some outstanding individual for the advancement of Food Technology, the $1000 Florasynth Fellowship Award is now open for qualified applicants. Nominees are selected by Department heads who are supervising the work of a candidate.

The Florasynth Fellowship is granted annually, to a young man or woman, under 35 years of age, engaged in senior undergraduate or graduate work, as a candidate for an advanced degree, in recognized educational institutions in the United States of America or Canada, which is conducting fundamental investigations for the advancement of Food Technology. The Fellowship Award is made annually to a person in a different institution each year, except that after three years, this Fellowship may be granted to a person studying in an institution where the Fellowship has been held previously.

Candidates for the award are selected by the Committee on Awards. The Fellowship is administered by the Institute through the Office of the Secretary of the Institute, with the advice and counsel of the Chairman of the Committee.

Procedure. Nomination for the Fellowship Award is made to the Office of the Secretary of the Institute, in behalf of the proposed candidate, by the head of the Department who supervises the undergraduate or graduate work of the candidate. Application must be made in letter form, giving the customary essential personal and academic information with respect to the candidate:

A. Name, nationality, sex, age, marital status.

B. Educational and experience background, college or university scholarship record in transcript, noteworthy accomplishments in research, reasons for proposing the candidate for the Fellowship Award.

In order to qualify, the candidate must have a better-than-average scholastic record/and or a B.Sc. or equivalent, preferably with honor, from an institution of recognized standing and shall have unusual qualities of character and ability in research.

The Fellowship Award is for the academic year. Nominations for the Fellowship Award for 1956-57 must be received at the Office of the Secretary of the Institute not later than February 1st, 1956. Selection of the winner is made by the Committee on Awards.

The name of the successful candidate is given to the President of the Institute who notifies the candidate with a copy of his letter of notification to the Head of Department who proposed the name of the candidate. The name of the recipient of the Fellowship Award will be announced by the President of the Institute at the Annual Meeting of the Institute in St. Louis, in June, 1956.

Announcement of General Foods Fund Inc. Fellowship Awards for 1956-1957

Complete details on the General Foods Fund Inc. Fellowships will be found in the paragraphs that follow. This is the first of two announcements of the 1956-1957 Awards.

Funds for the Awards are provided by The General Foods Fund, Inc., 250 Park Ave., New York 17, N. Y., a charitable foundation supported by General Foods Corporation, to establish a graduate fellowship program in the field of food science to be administered by The Institute of Food Technologists, Inc. The fellowships are granted annually—no more than two to the same educational institution for the same calendar year. They are renewable upon application to and approval by the Awards Committee for a maximum of three years, in order to provide for continuity of studies leading to a doctorate degree, if the candidate so plans. However, candidates who plan only a year of research after obtaining the Bachelor's Degree, or who plan to read for a Master's Degree, are not excluded from these fellowship grants.

Procedure

Candidates for these Fellowships are selected by the Committee on Awards from a roster listing all applicants submitted by and endorsed by the graduate schools where the applicants plan to pursue their studies. These Fellowships are administered by the Institute through the office of the Secretary of the Institute with the advice and counsel of the Chairman of the Awards Committee.

Fellowships are awarded annually, three each year, to deserving and outstanding United States or Canadian citizens, engaged in senior undergraduate or graduate work in recognized educational or research institutions in the United States of America or Canada, in basic or applied chemistry, chemical engineering or related sciences, which may involve new physical or other procedures, directed to extending or improving knowledge in some phase of food conservation, food production or food processing, rather than primarily for research in the fields of nutrition, bacteriology or analytical chemistry.

Applications must be in letter form, giving the customary essential personal and academic information with respect to the applicant:

A. Name, nationality, sex, age, marital status, physician's statement with respect to the general health and physical condition of applicant.

B. Educational and experience background, college or university scholarship record, noteworthy accomplishments in research and the purpose of applicant in applying for Fellowship Award.

In order to qualify, the applicant must be a senior undergraduate student, with better than average scholastic record at an institution of recognized standing; or, a graduate student with a B.Sc. or equivalent, preferably with honors, from an institution of recog-

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The young lady in the picture has brought home from London the second prize in the 1954 international beauty contest. The gentleman is by trade a master baker. Both are employed by Eastman Kodak Company in essentially similar jobs, for which each has high qualifications.

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He, surrounded by chemists, bakes all day. The chemists keep measuring the exact monoester content* of every production run of Myverol® Distilled Monoglycerides. They also make other chemical tests known to measure factors important for food components. No Myverol order leaves the plant until these chemists are satisfied; but then, just to make sure that some chemically negligible factor has not tripped us up, we have our master baker bake with it and evaluate his results with a skeptical old pro's eye. If he's happy, then we are too, as we go home to dinner clutching our individual fair shares of his labors.

For technical counsel and a cost analysis on the use of Myverol Distilled Monoglycerides in any food fat product write ***Distillation Products Industries,*** Rochester 3, N. Y. Sales offices: New York, Chicago, and Memphis • W. M. Gillies and Company, Los Angeles, Portland, and San Francisco • Charles Albert Smith Limited, Montreal and Toronto.

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nized standing. In either case, the applicant must have an approved plan of research in Food Technology and acceptance by the Graduate School of the institution in which the applicant proposes to hold the Fellowship. In presenting his application, the applicant should indicate his definite intention, on his word as a gentleman, to carry through with his approved research plan for the period of time for which the Fellowship Award is made insofar as it is humanly possible.

Three letters of recommendation must be forwarded separately to the Office of the Secretary of the Institute by Deans, Heads of Departments and/or Professors, who have supervised research work of the applicants. These letters should present essential facts regarding the scholarship or record transcript thereof, character and personality, ability to cooperate and capacity for work and achievement of the applicants. Also needed is a statement by the Head of the Department where the work will be done, endorsing the applicant and accepting for the school the responsibility connected with the acceptance of the Fellowship Award.

The Awards for the Fellowship are for the full calendar year and the total of the award shall be paid to the school at the beginning of the initial school term. This award will be used for three purposes: (a) to pay for living expenses of the chosen student at a minimum rate of $200/month ($2,400/year); (b) to pay all academic fees for the student and (c) the remaining monies will be allocated to the department fund in the department in which the student is working.

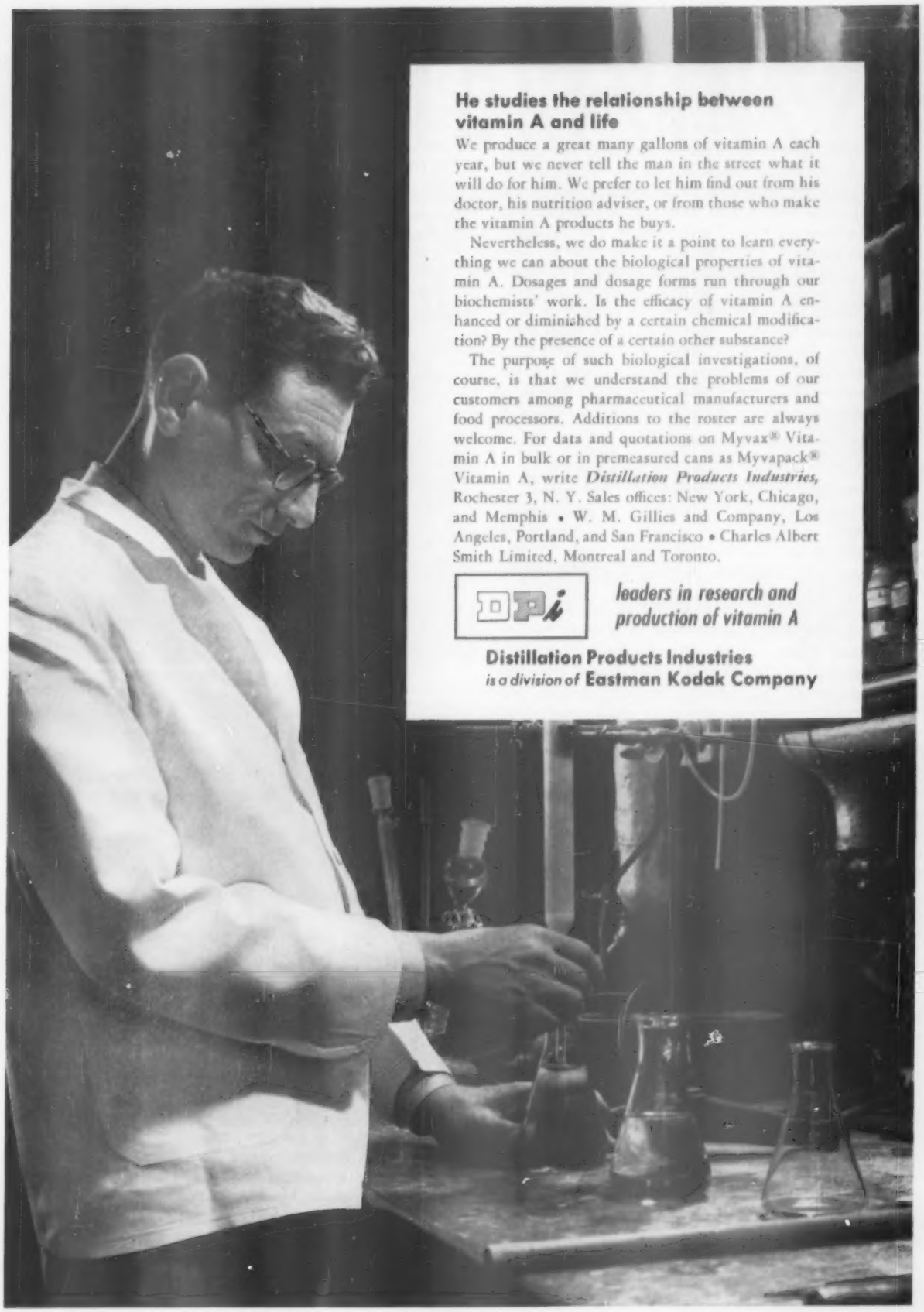
Applications for Fellowship Awards must be received at the Office of the Secretary of the Institute, not later than February 1st, 1956.

The names of the recipients of the Fellowships will be announced by the President of the Institute at the Annual Meeting of the Institute at St. Louis in June.

Monsanto Award Given to Two Papers in 1955

The judges for the Monsanto Award, the prize given for the best paper delivered before an Annual Meeting of the Institute of Food Technologists, selected two winners at the Columbus, Ohio, meeting. The excellent qualities of both papers, together with the competency with which they were presented, left little to choose between them.

The two papers were: "Some Aspects of Canning Soft Drinks" by H. T. Johnson, A. W. McAlpin, and Anna May Schenck, and "The Digestion and Absorption of Fat" by F. H. Matson. The first-mentioned paper, based on work done by the Metal Research Division of the Continental Can Company, Chicago, will appear in the December issue of FOOD TECHNOLOGY. The second paper, reporting studies conducted by the Research Division of the Procter and Gamble Company, Cincinnati, Ohio, will appear in FOOD RESEARCH for January-February.



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Gerber Baby Foods $6,000 Post-Doctorate Fellowship (1957) Announced

The Gerber Baby Foods Fund of Fremont, Michigan, a charitable foundation supported by Gerber Products Company, has established a Post-Doctorate Research Fellowship in the field of food science, to be administered by The Institute of Food Technologists, Inc. Winner of the first award is Dr. Austin C. Wagenknecht, Department of Food Science and Technology, New York State Agricultural Station, Cornell University, Geneva. The Fellowship was established for the purpose of promoting research in some newer phase of food technology. Dr. Wagenknecht will work on vegetable lipids, specializing in the enzymological aspects and the biochemistry of these components of vegetable products. He will take up residence at the University of Illinois in February, 1956.

Applications are in order for the second Gerber Award (1957) and any citizen of the United States or Canada holding a Ph.D. degree or an equivalent academic degree and having the necessary qualifications to undertake post-doctorate studies in a recognized educational or research institution may apply for the Fellowship. The applicant must be acceptable to the institution in which he plans to pursue his studies.

The Fellow will be selected by the Institute of Food Technologists Committee on Post-Doctorate Awards after review of all of the applications submitted. The Committee will make their selection based upon the candidate's ability, as judged from his previous performance and personal references, as well as their judgment of the potential value of the proposed research in the advancement of knowledge and human welfare. The Committee is guided by the general policy of selecting awardees who are not only well qualified in their particular field, but are capable of evaluating the nutritional aspects of their research. Although the Fellowship need not be limited to nutritional research, nutritional aspects should not be neglected.

The application for a Fellowship must be in letter form giving the customary essential personal and academic information with respect to the applicant. The application and supporting papers must be submitted in duplicate.

In addition, the application should present a research program stating the purpose of the research and its significance as well as a brief outline of the experimental procedure for accomplishing these objectives.

The application must also be accompanied by a letter of acceptance from the Head of the Department in which the work will be done.

Candidates should have at least three persons, under whose instruction they received their advanced degree, send confidential letters of support to the Executive Secretary, Institute of Food Technologists. These letters should cover in detail the previous work of the applicant and an evaluation of his suitability to undertake the proposed research. Address applications to the Executive Secretary, Institute of Food Technologists, 176 West Adams Street, Chicago 3, Illinois.

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Books

ORGANIC PEROXIDES. THEIR CHEMISTRY, DECOMPOSITION, AND ROLE IN POLYMERIZATION. Arthur V. Tobolsky and Robert B. Mesrobian. Interscience Publishers, Inc., New York, 197 p., 1954.

Because of their importance in chemistry and chemical technology interest in organic peroxides continued unabated since the publication in 1931 of Ruche's text on their use. During the period of 1950-1953, four important reviews and Eggersglüss' text in German appeared. Tobolsky and Mesrobian have reviewed the literature largely up to 1951, although occasional references to 1953 publications are cited. The preparation and properties of the more important classes of organic peroxides (hydro peroxides, dialkyl and diar alkyl peroxides, peroxy acids, diacyl and diaroyl peroxides, and peroxy derivatives of aldehydes and ketone) are briefly summarized, the physical chemistry of their decomposition is discussed, and their role in the initiation of homogeneous vinyl polymerization is treated in somewhat greater detail. Information of particular value to

(Continued on page 18)

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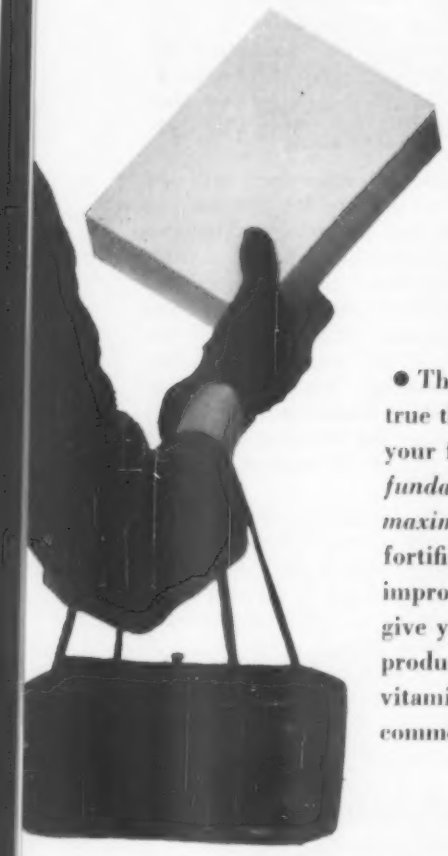

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BOOKS

(Continued from page 14)

food scientists and food technologists on the properties and factors influencing the formation of organic peroxides occurring during the oxidative rancidity of oils and fats, the nature of the reactions which they induce, and analytical methods suitable for their determination will not be found except in a very brief way. The section on the decomposition of organic peroxides is devoted largely to the decomposition into free radicals capable of initiating chain reactions such as polymerization and deals largely with the homolytic decomposition of butyl and benzoyl peroxides and related products. The physical constants of selected organic peroxides, explosiveness of peroxides and a list of commercially available organic peroxides are summarized in the appendix. The book will be useful as an introduction in English to the organic chemistry of peroxides and to the chemistry of polymerization reactions of vinyl monomers initiated by peroxide decomposition.

M. A. JOSLYN
Berkeley, Calif.

THE LIPIDS. VOLUME II: BIOCHEMISTRY. Harry J. Deuel, 919 pages. Interscience Publishers, Inc., New York, 1955.

This volume includes the biochemistry of digestion, absorption, transport and storage of fats and other lipids in the animal body. Originally the author intended to include also in this volume: biosynthesis, metabolism, oxidation, and the nutritional value of the lipids. Because of the recent large increase in material available, a third volume to be published later will include these latter topics.

Chapter II, the digestion and absorption of fats in the gastro-intestitnal tract, includes the enzymes concerned with digestion, the role of bile in lipid absorption, pathways of absorption, methods for the study of fat and lipid absorption, the digestion, absorption and transport of fats and factors affecting the rate of absorption of fats.

Chapter III deals with the digestibility of fats, methods for the study of digestibility, and factors affecting the digestibility of fats.

Chapter IV, the digestion, absorption, and digestibility of lipids other than fats includes the phospholipids, waxes, higher aliphatic alcohols, sterols, hydrocarbons, carotenoids, and fat soluble vitamins.

Chapter V, the blood lipids, includes the nature of the blood lipids, quantitative relationships, blood level, site of synthesis, turnover rate and factors altering their concentration.

Chapter VI deals with the occurrence of lipids in the animal as a whole, and Chapter VII with their distribution in specific tissues and in their secretions. The index includes a list of the generic names of plant and animal sources from which lipids are derived.

The book represents a very comprehensive review of the important literature in the field covered. It will prove useful to students, teachers, and research workers.

HENRY R. KRAYBILL
Chicago, Illinois

IFT to Co-Sponsor First International Symposium on "Physics in the Food Industry" in March 1956

Host Organization Is Southwest Research Institute, San Antonio, Texas

First international symposium on "Physics in the Food Industry" sponsored jointly by Southwest Research Institute and the Institute of Food Technologists, will be held in San Antonio March 15-16, 1956, at the Plaza Hotel. John O'Meara of Southwest Research Institute is program chairman for the symposium. Planning committee members include Dr. Laverne E. Clifcorn, president, and Colonel Charles S. Lawrence, executive secretary of the Institute of Food Technologists.

Purpose of the symposium is to explore with key technical people in the food industry the contributions physics can make to preserving, packaging and processing foods in the future. Outstanding authorities in the engineering and scientific fields related to food will present for discussion technical papers on applications of physics to the food industry. Participants will consider recent developments in, and the future of, Ultrasonics, X-Ray and Gamma-Ray Inspection, Electrostatistics, Dielectric Heating, Radiation Sterilization, Radiofrequency Spectroscopy, and related subjects. Attendance is expected to exceed 100 technologists and industry representatives.

Activities for the two-day symposium include a banquet at the Plaza Hotel and a tour of Southwest Research Institute, winding up with a barbecue on the grounds. The meeting is scheduled at the end of the week and visitors who so desire can make arrangements for a week-end side trip to Mexico.

All technical papers and discussions will be reproduced in the proceedings of the meeting to be published for general distribution.

Selected Abstracts*

ANALYTICAL METHODS

Determination of tannins and related polyphenols in foods. Comparison of Loewenthal and pro methods.

SMIT, C. J. B., JOSLYN, M. A., AND LUKTON, A. *Anal. Chem., 27,* 1159-62 (1955).

The volumetric permanganate titration and the colorimetric phosphomolybdictungstate reduction procedure were compared for pure polyphenols, com. tannins, and partially purified fruit tannins. The permanganate titration gave significantly higher results for catechol, hydroquinone, pyrogallol, and chlorogenic acid, and lower results for phenol, resorcinol, catechin, and quercetin. With com. tannin prepns. the results were lower but were essentially similar for fruit tannins. Changes in absorption spectra during titration with permanganate and changes in redox potential are reported.

Color reagent for paper chromatography of steroids.

BODANSZKY, A., AND KOLLONITSCH, J. *Nature, 175,* 729-30 (1955).

* These Selected Abstracts are made available to FOOD TECHNOLOGY through the cooperation of Dr. H. A. Campbell and the General Foods Corporation of White Plains, N. Y. The abbreviations found in these abstracts are similar to those used by Chemical Abstracts.

(Continued on page 20)

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SELECTED ABSTRACTS

(Continued from page 18)

Acid aniline phthalate in alc. soln., Partridge's reagent for sugars, is suitable for a color reaction to identify Δ4 keto steroids on paper.

BIOLOGICAL SCIENCES

BIOCHEMISTRY

Separation of neutral proteins on ion-exchange resins.

BOARDMAN, N. K., AND PARTRIDGE, S. M. *Biochem. J., 59,* 543-52 (1955).

Closely related neutral proteins, such as the hemoglobins, may be successfully sepd. by elution chromatography using columns of IRC-50. For the successful sepn. of neutral proteins which are susceptible to denaturation, it is best to arrange conditions so that all the proteins in the mixt. move down the column with R_f values >0.5. This can be done by a suitable selection of the pH and Na^+ concn. of the eluting buffer.

Separation of flavins by ion-exchange resins.

YAGI, K., OKUDA, J., AND MATSUOKA, Y. *Nature, 175,* 555-6 (1955).

The anion-exchange resin, 'Dowex-1,' was found to be the most suitable. The flavin compds. were sepd. completely from each other, and the methods described can be applied for the fractional detn. of the nucleotides of riboflavin and the purification of flavin adenine dinucleotide.

A method for the quantitative determination of C-terminal amino acid residues.

FOX, S. W., HURST, T. L., GRIFFITH, J. F., UNDERWOOD, O. *J. Am. Chem. Soc., 77,* 3119-22 (1955).

A carboxoid method which is analogous to a previously described aminoid method is reported. The method appears to offer a no. of advantages over other C-terminal procedures which have been described. Among these are stereospecificity, quant. applicability, and ease of operation such as freedom from the need for fractionation.

A colorimetric method for the estimation of glutamic acid in protein hydrolyzates.

ZAMIR, A., AND LICHTENSTEIN, N. *Anal. Chim. Acta, 12,* 577-9 (1955).

On heating with hydroxylamine and on subsequent treatment with $FeCl_3$, pyrrolidonecarboxylic acid (I) gives a color reaction. This reaction can be used for the quant. estn. of glutamic acid in protein hydrolyzates since this acid is almost completely converted into (I) at 125° and pH 3-4.

Potato pyrophosphatases.

NAGANNA, B., RAMAN, A., VENUGOPAL, B., AND SRIPATHI, C. E. *Biochem. J., 60,* 215-23 (1955).

Potatoes contain a labile alk. pyrophosphatase besides the already known acid phosphatase and acid pyrophosphatase. No alk. phosphatase could be demonstrated. The alk. PP-ase is active only in the presence of 0.01-0.02 *M* Mg^{++}.

BOTANY

Germination of rice embryo under water and its relation of growth to endosperm fractions.

SIRCAR, S. M., DAS, T. M., AND LAHIRI, A. N. *Nature, 175,* 1046-7 (1955).

It appears that the amt. of auxin or some unknown factor present in the rice endosperm is more than optimal for early growth of the embryo. Growth may be accelerated by elimination, up to a limiting value, of endosperm fractions. There are differences in the growth of mesocotyl, coleoptile and root under water and in air when different amts. of endosperm are removed.

Cacao research.

Nature, 175, 802-3 (1955).

Report of the Cacao Research Scheme, Imperial College of Tropical Agriculture, Trinidad. A review of the research at this college to improve the yield and quality of cacao beans.

MICROBIOLOGY

Microbiological process report, continuous fermentation. A discussion of its principles and applications.

MAXON, W. D. *Appl. Microbiol., 3,* 110-22 (1955).

As the technology of fermentation develops, it seems inevitable that manufacturers will turn to this type of operation for other products. The advantages to be gained, whether increased output, automatic control, or product uniformity, all become available when the difficulties of contamination, genetic instability, and so forth are solved. This discussion was intended to summarize the information on the subject presently available and to provide a background for new developments and a starting point for new ideas. 53 references.

Pathways of carbohydrate metabolism in microorganisms.

GUNSALUS, I. C., HORECKER, B. L., AND WOOD, W. A. *Bacteriol. Revs., 19,* 79-128 (1955).

The reactions leading to products of carbohydrate metabolism by microorganisms *via* pyruvate or other intermediates of fermentation or oxidation pathways have been discussed insofar as enzymatic reactions for their formation are known or may be deduced with reasonable certainty. Although in some instances, the reactants may be formed by the pathways of carbohydrate metabolism, and in still others the mechanisms may be similar to known reactions in glycolysis or other pathways, these are beyond the scope of the present effort. 431 references.

Synthesis of lipids in resting cells of Saccharomyces cerevisiae.

KLEIN, H. P. *J. Bacteriol., 69,* 620-7 (1955).

Cells of *S. cerevisiae,* cultivated under aerobic conditions, contain considerably higher quantities of fatty acids and nonsaponifiable lipids than do cells grown anaerobically. In addn., the unsaponifiable fraction of anaerobic cells was found to be rich in material not giving a test for sterols. Subsequent aeration of anaerobic cells in phosphate buffer resulted in 3 to 8-fold increases in sterol within eight hours, with no significant increase in the total nonsaponifiable matter. During this period, fatty acids were also produced. Glucose, when added to the aeration mixture, served to stimulate the synthesis of large quantities of lipids. These were found to arise almost exclusively from the exogenous C source. An apparent lack of utilization of acetate and a possible physiological role of the newly-formed lipids are discussed.

Detection of a new serotype of Escherichia coli, E. coli O127:B8, associated with acute diarrhea in infants.

COOPER, M. L., WALTERS, E. W., AND KELLER, H. M. *J. Bacteriol., 69,* 689-94 (1955).

A total of 158 infants and 82 adults were cultured for the presence of certain serotypes of *E. coli* assocd. with diarrhea in infants and other intestinal pathogens during a 4 mo. period. *E. coli* 0127 was isolated from 44 infant patients and from one apparently healthy nurse in attendance. This type of *E. coli* was found in practically pure culture in rectal swab cultures from infants in the acute phase of their disease. The details of biochem. culture reactions and serological studies are presented.

The inhibiting effect of serine upon the growth of the indigenous flora of cream filling.

CASTELLANI, A. G., MAKOWSKI, R., AND BRADLEY, W. B. *Appl. Microbiol., 3,* 132-5 (1955).

Serine, cysteine and thioglycollic acid inhibit the growth of spore forming bacilli which normally spoil properly cooked vanilla cream fillings. The effect of serine is lessened by Na propionate. Coconut and cocoa completely neutralize the bacteriostasis of serine on Staphylococci but the inhibition is pronounced in a pineapple cream filling.

Maple sirup. IX. Microorganisms as a cause of premature stoppage of sap flow from maple tap holes.

NAGHSKI, J., AND WILLITS, C. O. *Appl. Microbiol., 3,* 149-51 (1955).

Premature "crying" of maple tap holes which can reduce annual yields by 20-75% was correlated with growth of microorganisms and not with phys. drying.

NUTRITION

Diet, cholesterol and atherosclerosis.

Nutrition Revs., 13, 138-40 (1955).

A relation between diet, serum cholesterol and atherosclerosis is well recognized. Available evidence points to the fat content of the diet as an important factor in this relationship. There is a paucity of information available concerning the relation of

(Continued on page 22)

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SELECTED ABSTRACTS

(Continued from page 20)

serum cholesterol levels and of atherosclerosis to other dietary factors such as total caloric intake, the bulk or residue of the diet, and relation of fat intake to that of other nutrients. Although a relation between dietary factors and atherosclerosis has been apparent for many years, the specific factors involved and their role in the genesis of atherosclerosis in man remain elusive.

Fat as a required nutrient of the diet.

DEUEL, H. J. *Federation Proc., 14,* 639-48 (1955).

It is as yet a moot question whether the beneficial effects of fats, nutritionwise, are to be ascribed solely to the essential fatty acid (EFA) which they contain or whether triglyceride fats have a specific nutritional value *per se.* The beneficial effects of high-fat diets on pregnancy, lactation, and possibly also on growth can probably be largely, if not entirely, ascribed to their EFA content. On the other hand, there is no pos. evidence that the improved cal. efficiency resulting from the associative dynamic effects, or the sparing action of fats, on certain phases of protein metabolism are necessarily functions of the EFA.

Life span of "yellow" mice fed enriched diets.

SILBERBERG, R., SILBERBERG, M., AND RILEY, S. *Am. J. Physiol., 181,* 128-30 (1955).

A high fat diet significantly shortened the life span of 'yellow' mice while a high carbohydrate diet, although causing considerable over wt. exerted no injurious effect on life span.

Choice of diet by rats. V. Choice of diets containing various members of the vitamin B complex.

TRIBE, D. E., AND GORDON, J. G. *Brit. J. Nutrition, 9,* 200-2 (1955).

The food preferences of 34 "Lister" rats, some of which had received diets deficient in the vitamin B complex, were examd. in an expt. involving the use of 6 diets, which differed only in their contents of various members of vitamin B complex. The rats that had received diets deficient in the vitamin B complex showed a marked preference for diets contg. thiamine and riboflavin. The behavior of the other rats was similar but less marked.

Growth and amino-acid intakes of children on a cereal-legume-vegetable diet.

BAPTIST, N. G., AND DE MEL, B. V. *Brit. J. Nutrition, 9,* 150-70 (1955).

After a preliminary observation period on a mixed diet contg. animal protein, the hts. and wts. of 23 Ceylonese children aged 1-6 yrs. were studied after they had been given an entirely vegetable diet or the same diet with a supplement of skim milk. No statistically significant difference was found between the 2 groups as a whole. However, the children between the ages of 3½ and 6 yrs. on the entirely vegetable diet gained somewhat more in wt. but decidedly less in ht. The essential amino-acid content of the diets has been computed and approx. requirements for growth of children are suggested. It is concluded that a suitable mixt. of vegetable proteins can support growth in children.

Effect of food administration on weight gains and body composition of normal and adrenalectomized rats.

COHN, C., SHRAGO, E., AND JOSEPH, D. *Am. J. Physiol., 180,* 503-7 (1955).

These findings indicate that the overall rate of utilization of the foodstuffs by the animal lacking his adrenals does not differ from normal when the food intake is "optimal." Force fed normals contain more body fat than ad libitum-eating normal animals receiving the same diet and gaining the same amt. of wt.

PHARMACOLOGY AND TOXICOLOGY

Review of current knowledge of toxicity of cholinesterase inhibitor insecticides.

HAZELTON, L. W. *J. Agr. Food Chem., 3,* 312-19 (1955).

The common property of the org. phosphate-type insecticides now in com. use is their ability to inhibit cholinesterase. The acute toxicity of these materials is a reflection of this enzyme-inhibiting action and varies appreciably with different members of the group. Subacute toxicity develops only when inhibition exceeds cholinesterase regeneration rate, particularly in the red blood cells. Under use conditions residue hazard appears to be negligible. 80 references.

Nutritional changes in diets exposed to ethylene oxide.

HAWK, E. A., AND MICKELSON, O. *Science, 121,* 442-4 (1955).

This paper presents evidence that when diets are treated with ethylene oxide the nutritional properties are impaired.

Effect of feeding dogs the flesh of lethally irradiated cows and sheep.

WASSERMAN, R. H., AND TRUM, B. F. *Science, 121,* 894-6 (1955).

A 140 day feeding test indicated that the flesh from lethally irradiated cows or sheep was not grossly toxic or injurious to the canine.

PHYSIOLOGY AND MEDICINE

Stannous and fluoride compounds for topical dental treatments.

Nutrition Revs., 13, 134-6 (1955).

Recent studies of reviews on different aspects of fluorides and tooth decay are discussed. Stannous chlorofluoride soln. seems to show promise as a topical dental treatment.

Stress and disease.

SELYE, H. *Geriatrics, 10,* 253-61 (1955).

The cumulative effect of everyday stress may become pathogenic and add to the premature development of senility. Study was made of the precise pathways through which stress acts upon the various parts of the body and the findings correlated with observations from the world literature. The essential facts are summarized in a brief synoptic review for gerontologists.

The anticoagulant action in blood of sulfated derivatives of laminarin.

HAWKINS, W. W., AND O'NEILL, A. N. *Can. J. Biochem. Physiol., 33,* 545-52 (1955).

Laminarin, a polysaccharide from brown seaweeds, has been sulfated to produce compds. which show anticoagulant activity in blood *in vivo.* Derivs. of sulfamic acid were more active than simple sulfate esters. When tested in rats one sulfated β-aminoethyl ether deriv. was 40-50% as potent as heparin. Tests with rats and dogs indicated no harmful effects in the doses used.

Goiter production and prevention in rats.

VAN MIDDLESWORTH, L. *Science, 121,* 871-3 (1955).

Enlarged thyroid glands resulted in rats fed a diet of Pablum mixed cereal. This diet was more goitrogenic than a low I (Remington) diet designed to obtain such symptoms. It was suggested that the cereal may have contained a goitrogen.

Placebos.

LASAGNA, L. *Sci. American, 193,* 68-71, August, 1955.

An attempt is made to classify psychologically the people who react to placebos and those who do not. This information may be important in designing expts. in which placebos are used.

Skin symptoms of vitamin-B_6 deficiency in the dog.

HAWKINS, W. W. *Science, 121,* 880 (1955).

The author has been conducting expts. on vitamin B_6 deficiency in rats and dogs. Dogs on such diets have shown the typical hematological symptoms, but a lack of this vitamin has not been known to affect the skin or hair of dogs. However, some young dogs have had severe skin lesions after being given desoxypridoxine, a compd. regarded as a B_6 antivitamin.

DETERGENTS

Synthetic detergents and emulsifiers up to date.

MCCUTCHEON, J. W. *Soap Chem. Specialties, 31,* 50-61, July, 1955.

A review with an extensive listing of detergents by trade name, manufacturer, class and formula, main uses, form, % concn. and type. Three more articles are to follow.

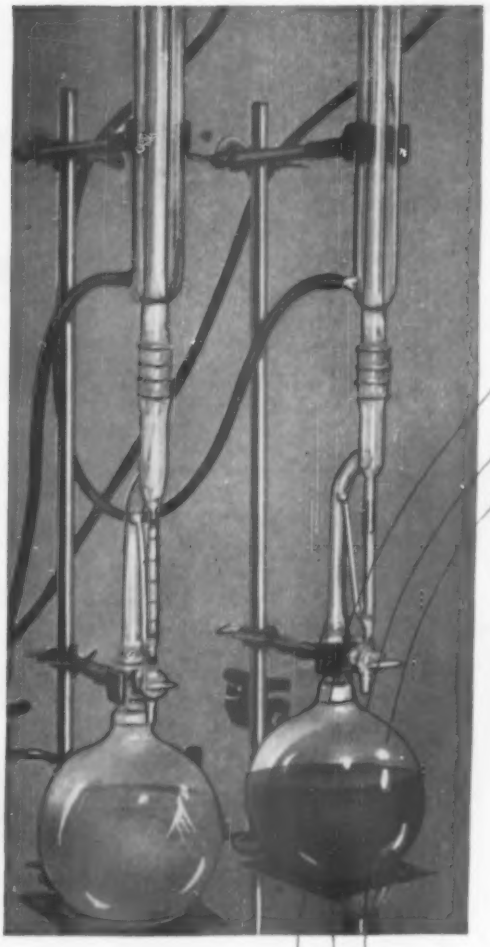
ENGINEERING AND PLANT EQUIPMENT

A versatile multistage extraction unit.

FENSKE, M. R., AND LONG, R. B. *Chem. Eng. Progr., 51,* 194-8 (1955).

(Continued on page 26)

The Taste of Sunshine—All the Time



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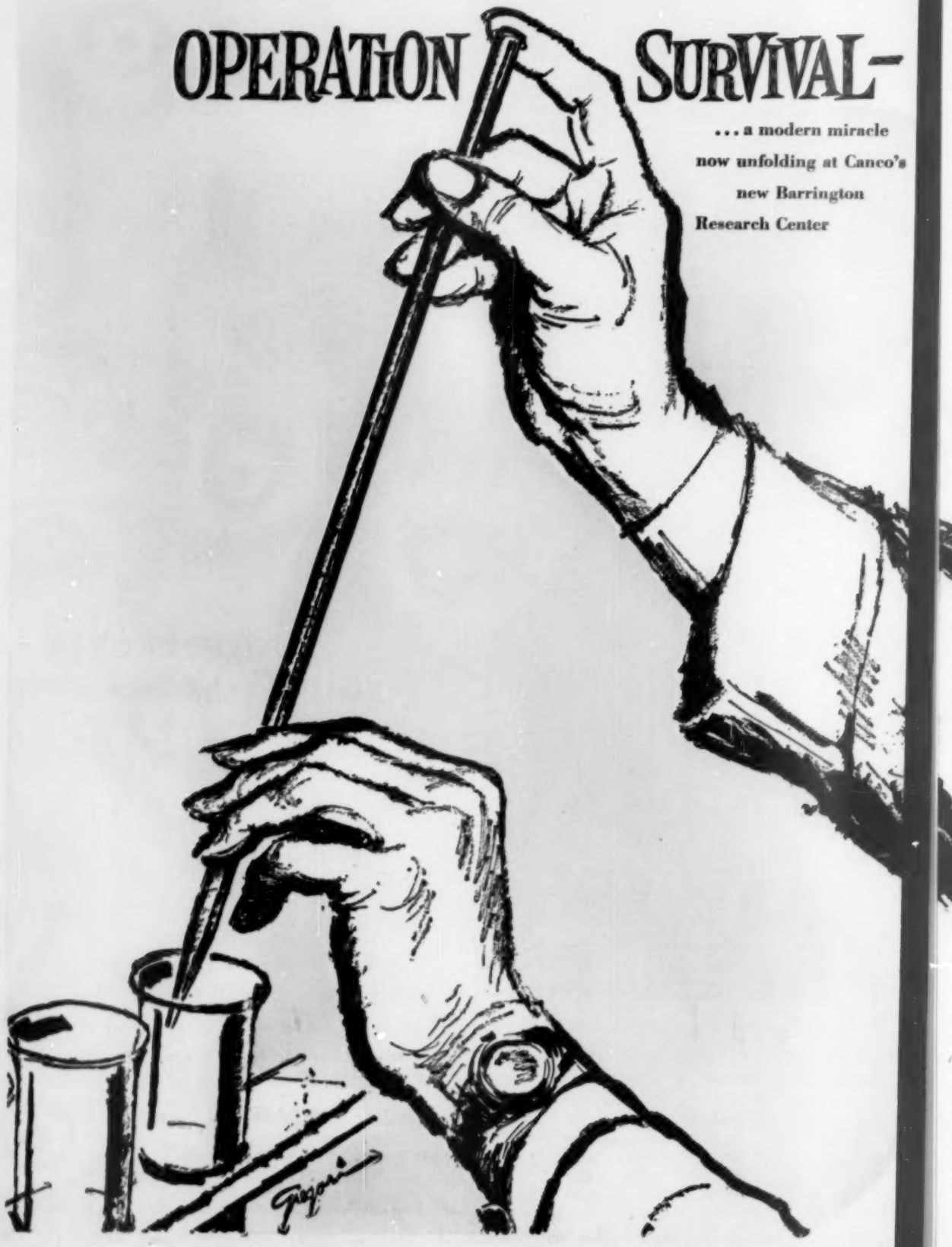

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SELECTED ABSTRACTS

(Continued from page 22)

An ideal mixer-settler extractor for pilot plant work is presented. A description of the unit and the expts. performed are also given.

FOOD AND FOOD TECHNOLOGY

FATS AND OILS

The component fatty acids and glycerides of coconut oils.

DALE, A. P., AND MEARA, M. L. *J. Sci. Food Agr., 6,* 162-6 (1955).

The data indicate that the compn. of coconut oils produced in widely scattered regions remains practically const. The oil consists of a very complex mixt. of mixed triglycerides, only 2 components of which (myristodilaurin and lauromyristopalmitin) occur to the extent of over 10%.

GELATIN AND GUMS

The N-terminal amino acid residues of gelatin. 3. Enzymic degradation.

COURTS, A. *Biochem. J., 59,* 383-8 (1955).

Gelatin was degraded by pepsin, trypsin, chymotrypsin and papain. The N-terminal residues of the hydrolyzates were detd. by Sanger's fluorodinitrobenzene technic. Attacks on similar peptide bonds are shown in all 4 cases. It is suggested that proteolysis occurs in 2 ways; one involving a random breaking of peptide bonds, the other involving a specific bond breaking action.

The function of gelatin as a setting agent in bakery products.

GLABAU, C. A. *Bakers Weekly, 165,* 40-2, June 6, 1955.

The quantity of gelatin to be used in making marshmallow seems to be directly related to the bloom strength.

MEAT AND POULTRY

Extraction of pigment from cooked cured-meat products.

ANDERTON, J. I., AND LOCKE, D. J. *Nature, 175,* 818-19 (1955).

A method is developed by which nitric oxide heme pigment of cooked and meat product is sol. in org. solvents.

ORGANIC CHEMISTRY

Alkaline-earth borohydrides and their application in organic syntheses.

KOLLONITSCH, J., FUCHS, O., AND GABOR, V. *Nature, 175,* 346 (1955).

It was pointed out that the alk.-earth metal borohydrides are very suitable for the reduction of ketones and aldehydes to the corresponding alcs.

PHYSICAL RESEARCH

Ionization in fatty acid monolayers on pure water.

SANDERS, J. V., AND SPINK, J. A. *Nature, 175,* 644-5 (1955).

Former measurements of force-area characteristics and surface potentials show well-defined changes occurring at about the pH at which the carboxyl group is expected to be appreciably ionized, and these changes have been ascribed to the ionization. The author found that the effects can be caused by impurities in the substrate and that, in fact, ionization has much less effect on the properties of stearic acid monolyers than has been thought previously.

Particle shape coefficients.

HEYWOOD, H. *J. Imp. Coll. Chem. Eng. Soc., 8,* 25-33 (1954, publ. 1955).

A method for estg. the vol. and surface of geometric and/or irregularly shaped particles is presented. The particles covered by this method can be microscopic in size.

Studies on powdery preparations of colloids and colloidal solutions.

MIYGAWA, Y. *Japan. J. Exp. Med., 23,* 39-51 (1953); *Biol. Abstr., 29,* No. 10420 (1955).

The methods of manufg. the powdery prepns. of colloid or colloidal solns. of metals, minerals, blood, plasma, serum, fat, bacteria and some kinds of medical drugs were described. The methods differ according to the kind of materials. At the time of use, the prepn. is dissolved in H_2O, making a typical colloidal soln.

Studies on carrageenin: the effect of shear rate on viscosity.

MASSON, C. R., AND GORING, D. A. I. *Can. J. Chem., 33,* 895-903 (1955).

The viscosity of aq. solns. of carrageenin of high mol. wt. was markedly dependent on the rate of shear. The shear-dependence increased with decrease in the concn. of added electrolyte.

A rapid method for iso-electric point determination.

LABGIER, J. F. *Biochim. et Biophys. Acta, 17,* 341-5 (1955).

An accurate and rapid method of detg. iso-elec. pts., by means of a 4-compartment electrophoresis cell, is described. Using this method the iso-elec. pts. of human serum albumin and rabbit serum albumin were detd. in different buffers.

WATER, SEWAGE AND SANITATION

Basic problems in the detection of microbiological air pollution.

GOETZ, A. *Am. Ind. Hyg. Assoc. Quart., 16,* 113-20 (1955).

The problems involved in the microbiol. assay of aerosols are in part due to the generally low concn. of microorganisms and their coexistence with large nos. of particles of potentially inhibitory nature—and in part due to the relative stability of such aerosols at low concns. and their instability at high concns. which can cause misleading losses of viability in the sampling process.

MISCELLANEOUS INFORMATION

A constant flow suction unit, for aerosol sampling work.

SCHMIDT, A. C., AND WILTSHIRE, L. L. *Am. Ind. Hyg. Assoc. Quart., 16,* 134-40 (1955).

A suction unit has been developed and tested which will automatically draw air into filter samplers at a pre-set constant rate in spite of wide variations in the resistance of the collecting media. Two models are described, one having a fixed flow rate of 10 cfm and the other being adjustable between 1 and 15 cfm. Components were selected to make them portable and to enable them to operate under adverse field conditions.

On foam properties of beer.

KLOPPER, W. J. *Wallerstein Lab. Communs., 18,* 123-35 (1955).

A review of methods of analysis for head retention in beer and factors rsponsible for foam duration and foam adhesion.

PATENTS

Method of preserving cream-custard type food products and the resulting composition.

CASTELLANI, A. G. *Assignor to American Institute of Baking.* 2,711,976, June 28, 1955.

A food compn. of the cream-custard type contg. a bacteriostatic amt. of a microorganism growth inhibitor selected from the group consisting of serine, glycine, cysteine and thioglycollic acid.

Obituary

It is with deep sorrow that we report the news of the death of a prominent overseas member of the Institute of Food Technologists, Mr. Ir A. K. Zweede, Director of the Institute for Research on Storage and Processing of Horticultural Produce, more generally known as the IBVT of Wageningen, Netherlands. Mr. Zweede and his wife were involved in a serious motor car accident on September 3, 1955, and neither survived. "The IBVT suffers a great loss by the death of its director," writes Mr. C. Boudewijn, President, "he had a very special skill in developing the research work of the Institute."

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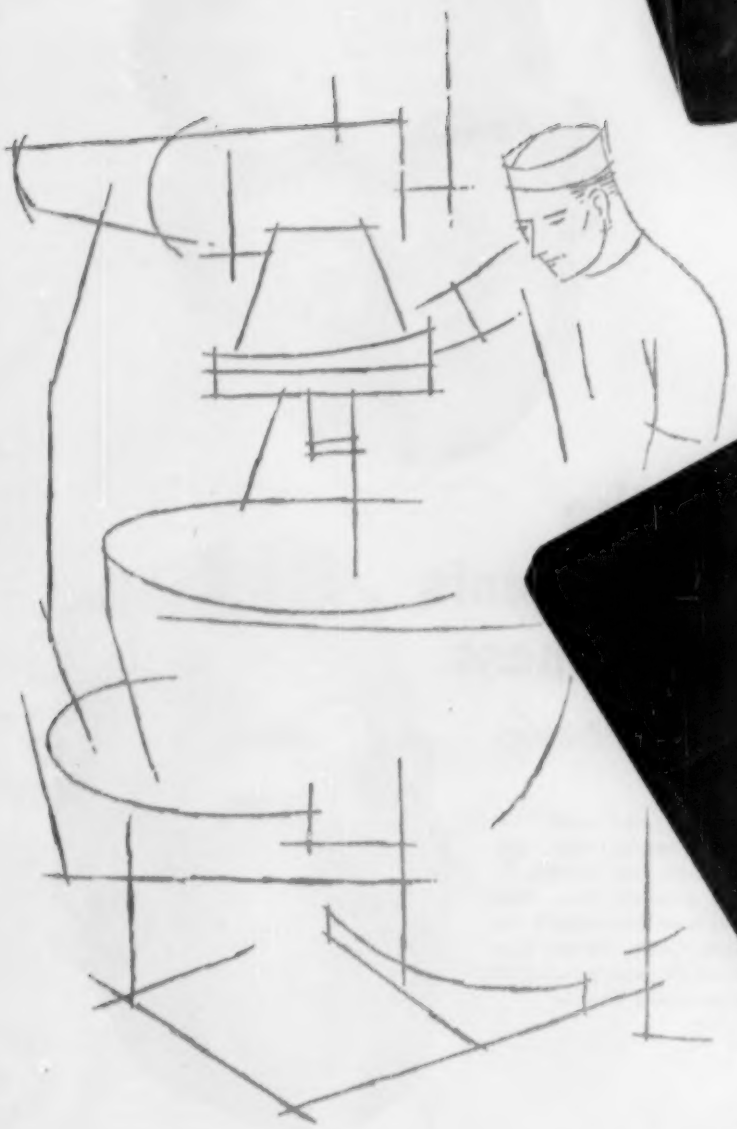

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Extension of Food Storage Life by Irradiation[a,b,c]

B. E. PROCTOR, J. T. R. NICKERSON, J. J. LICCIARDELLO, S. A. GOLDBLITH, AND E. E. LOCKHART

Department of Food Technology, Massachusetts Institute of Technology, Cambridge, Mass.

(Manuscript received June 21, 1955)

Certain meat and vegetable products were treated with high-voltage cathode rays to extend the storage period at refrigerator temperatures above freezing. Organoleptic evaluation indicated that some foods treated in this manner may be held at refrigerator temperatures for periods lasting from several weeks to several months without significant change in acceptability. Bacterial increases and peroxide values of lipid components were also investigated.

Since 1946, numerous investigations have been reported concerning the use of ionizing radiations to destroy microorganisms in foods for the purpose of extending the storage life of such products when held at temperatures above freezing *(2-4)*. There are possibilities of treating food products with high-voltage cathode rays at levels that will destroy all microorganisms and of holding such irradiated food products at normal storage temperatures similar to those customary for heat-processed food products. However, these higher levels of cathode ray treatment may induce changes in food flavor that are difficult to mask or modify so that the food will be organoleptically acceptable.

As most spore-forming bacteria do not grow at refrigerator temperatures above freezing and vegetative types may be destroyed with comparatively low doses of high-voltage cathode rays, an investigation was undertaken to determine whether certain foods could be irradiated at levels sufficient to destroy psychrophilic bacteria without causing unacceptable flavor changes, thereby enabling increase in the storage life of refrigerated products so treated.

EXPERIMENTAL PROCEDURES

Preparation of samples for irradiation treatment. Asparagus stalks were cut to a length of approximately 4 inches. They were then blanched in live steam for 4 minutes, cooled in water, drained, packed and hermetically sealed in unlacquered, quarter-pound sardine cans.

Green beans were snipped and cut in 2-inch lengths. Blanching and packing procedures were the same as for asparagus.

Roots and crowns were trimmed from spinach leaves, and defective leaves were culled out. The leaves were washed, blanched for 4 minutes in live steam, and cooled in water. Packing procedures did not differ from those used for asparagus.

Pork sausage meat was prepared by grinding the meat trimmed from pork butts and mixing with seasoning (salt, pepper, and sage). The same amount of salt was used for samples that were to be irradiated as for control samples—0.28 oz. per pound. In the case of the spices, 0.12 oz. of black pepper and 0.04 oz. of sage were used per pound of product to be irradiated. Control samples contained 0.06 oz. of black pepper and 0.02 oz. of sage. Samples were packed in enameled cans 211 x 011 in size and hermetically sealed.

Fresh sausage links were prepared in a commercial packing house. To obtain suitable samples for control and for irradiation treatment, batches were prepared to contain the normal spice content, the normal spice content plus 0.25% of sodium ascorbate, and the normal spice content plus 0.5% of sodium ascorbate. Each type of sausage was packed in evacuated and tightly sealed saran bags, or in non-evacuated cellophane bags. Six links were placed in each package.

Into short rump and eye-of-the-round sections of beef, an aqueous solution of sodium glutamate and sodium fumarate was pumped with a hypodermic needle. Ten percent, by weight, of this solution was added to each beef section, of such concentration as to provide levels of 0.5% of glutamate and 0.3% of fumarate in the meat. Control (unirradiated) samples consisted of meat portions that had been treated with these chemicals and other similar samples that had neither been treated with chemicals nor irradiated. After pumping the solution into the portions of beef, the beef was cut into slices 12 mm. thick, which were hermetically sealed in enameled cans 211 x 011 in size.

Control samples of ground beef were prepared by grinding bottom-of-the-round beef through a $\frac{3}{16}$-inch plate. In preparing ground beef samples to which chemicals or free-radical acceptors had been added for control and irradiated samples, bottom-of-the-round beef was cut into cubes, and these were sprinkled with the chemical mixture. The cubes of meat were then ground through a $\frac{3}{16}$-inch plate. All ground beef samples were packed in enameled cans of the 211 x 011 size, and the cans were hermetically sealed.

Skinless frankfurters were prepared in a commercial packing house. At the time of manufacture and during the comminuting, sodium ascorbate was added in quantities of either 0.25 or 0.5% except for the controls, which were prepared without the addition of sodium ascorbate. The frankfurters contained no dry milk solids. They were packed in heat-sealed, double-layered cellophane bags, three units to the bag.

Methods of irradiating samples. Irradiation treatment was given with a 3 m.e.v. Van de Graaff electrostatic generator *(6)*. Samples were first subjected to high-voltage cathode ray treatment from one face of the packages as they passed along the moving belt transversed by the cathode ray beam. To attain adequate penetration of the rays, it was necessary to turn the samples over and irradiate them from the opposite face.

Samples were not irradiated at dose levels to destroy all organisms but at levels (from 8×10^6 to 1×10^8 rep) that would destroy all types of bacteria normally capable of growing at temperatures below 40° F. In all cases the dose of high-voltage cathode rays to which samples were subjected was checked by using the ferrous-ferric system of dosimetary *(7)*.

Storage procedures. All samples treated with high-voltage cathode rays were stored at refrigerator temperatures above freezing. Some of the control samples were frozen for purposes of preservation.

Bacteriological methods. Standard plate counts were made according to methods listed in *Standard Methods for the Examination of Dairy Products (1)*. The initial dilution was prepared in each case by placing 22 g. of the product and 198 ml. of chilled, sterile, distilled water in the sterilized top of a Waring blender and disintegrating the mixture for 3 to 5 minutes. Decimal dilutions were made from this 1:10 mixture.

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[a] Presented at the Fifteenth Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 14, 1955.

[b] Contribution No. 260 from the Department of Food Technology, Massachusetts Institute of Technology.

[c] The research reported in this paper was conducted during the period from July 1, 1953 to May 31, 1954 under Contract N140s-46199B as administered by the U. S. Naval Supply Research and Development Facility. The views and conclusions expressed are those of the authors and do not necessarily reflect the views or endorsement of the Department of the Navy.

and appropriate dilutions were plated in duplicate on tryptone glucose extract agar. Plate cultures were incubated at 30° C. for 48 to 72 hours before the counts were made.

The most probable numbers of anaerobic organisms were determined by inoculating 5 tubes of sterile liver broth with 1-ml. portions of an appropriate dilution of product and stratifying with sterile vaseline. This procedure was repeated for the two succeeding decimal dilutions. After an incubation period of 2 to 3 weeks at 37° C., tubes showing gas production and growth, or growth alone, were noted and the most probable numbers of putrefactive anaerobes and of total anaerobes were calculated from tables listed in *Standard Methods for the Examination of Dairy Products (1)*.

Peroxide number tests. A 50-g. sample of sausage meat was mixed with 25 g. of anhydrous sodium sulfate, and 150 ml. of petroleum ether was added. The mixture was allowed to settle after being stirred for 30 minutes with an electric stirrer. The ether was then filtered off into a weighed beaker and evaporated while a current of carbon dioxide was bubbled through the extract. The extracted fat was dried in a desiccator and weighed. A 60:40 mixture of glacial acetic acid and chloroform (50 ml.) was then added, followed by 1 ml. of saturated potassium iodide solution. This mixture was stirred for exactly 2 minutes, after which 100 ml. of 0.05% starch solution was added. Liberated iodine was titrated with 0.01 N sodium thiosulfate. The peroxide value was calculated as millimoles of peroxide oxygen per 1000 g. of oil according to the formula:

$$\frac{V \times N \times 0.5 \times 1000}{W}$$

where V represents milliliters of $Na_2S_2O_3$, N Normality, and W weight of sample in grams.

Organoleptic tests. Samples were prepared by different cooking methods and served to tasters. Meats were usually broiled, and vegetables were boiled. No salt or other seasoning was added to the samples before, during, or after cooking.

A scoring panel of 20 members was used, and judges were requested to rate the samples according to the following scale:

9—Like extremely
8—Like very much
7—Like moderately
6—Like slightly
5—Neither like nor dislike
4—Dislike slightly
3—Dislike moderately
2—Dislike very much
1—Dislike extremely

Mean flavor scores were determined for tested samples by totaling the individual ratings for a given product and dividing by the number of tasters. Calculation of the significance of the difference between means was done by the "t" method *(5)*.

RESULTS AND DISCUSSION

It was evident that spinach could be treated at higher levels of cathode ray irradiation than was possible with asparagus or green beans without developing undesirable flavors (Table 1). Irradiated spinach treated at a level sufficient to destroy psychrophilic bacteria had a higher organoleptic score after a 6-week storage period at 36-40° F. than did the frozen, unirradiated control. All samples were packed in hermetically sealed metal cans.

In the case of adequately packaged fresh pork sausage links it was also possible to irradiate with high-voltage cathode rays at a level sufficient to destroy psychrophilic bacteria without causing the development of objectionable off-flavors (Table 2).

When untreated fresh pork sausage links were held at refrigerator temperatures, there appeared to be a problem during the early storage period (approximately the first 10 days) associated with the development of rancidity in the fat. As storage was continued, the development of rancidity of the fat was overshadowed by decomposition products produced by bacterial action. At the end of a 3-week storage period at 36-40° F., unirradiated fresh pork sausage links, packed in either cellophane or saran with vacuum, had decomposed to such an extent through bacterial action that they could not be tested organoleptically.

Fresh pork sausage links irradiated at a level of 1×10^6 rep did not deteriorate bacteriologically during a storage period of 17 weeks at 36-40° F. The problem in this case was associated with the development of rancidity. So far as the prevention of rancidity in irradiated samples was concerned, packaging in saran with vacuum gave better results than packaging in cellophane (Table 3). The organoleptic score of fresh pork sausage packaged in saran with vacuum and treated with high-voltage cathode rays was still as high as 5 *(neither like nor dislike)* after a storage period of 120 days at 36-40° F.

A short test with sausage patties packed in hermetically sealed cans indicated that better organoleptic results might be expected with samples irradiated at a level of 1×10^6 rep and stored at 36-40° F. than with unirradiated controls stored at 0° F. (Table 4). After 14 weeks of storage the refrigerated irradiated sample (36-40° F.) was significantly better in flavor than the frozen control sample. The organoleptic score for the refrigerated irradiated sample was 6.83 (less than *like moderately* but more than *like slightly*) and the score

TABLE 1
Bacterial content and organoleptic evaluation of vegetables after irradiation and storage

Product	Irradiation treatment	Storage		Standard plate count per gram		Organoleptic score	Significance at the 0.5% level
		Weeks	Temperature	Before storage	After storage		
Asparagus	Control	0	0° F.	4,200	.....	6.84	Control significantly better
	1.0×10^6 rep	0	36°-40° F.	<300	.....	.....	
	1.0×10^6 rep	3	36°-40° F.	.....	<300	5.00	
Green beans	Control	0	0° F.	6,400	.....	6.30	Control significantly better
	1.0×10^6 rep	0	36°-40° F.	<300	.....	.....	
	1.0×10^6 rep	3	36°-40° F.	.....	<300	4.75	
Spinach	Control	0	0° F.	8,300	.....	5.11	Irradiated significantly better
	1.5×10^6 rep	0	36°-40° F.	<300	.....	.....	
	1.5×10^6 rep	3	36°-40° F.	.....	<300	6.42	
	Control	0	0° F.	8,300	.....	5.95	No significant difference
	1.5×10^6 rep	0	36°-40° F.	<300	.....	.....	
	1.5×10^6 rep	6	36°-40° F.	.....	<300	6.20	

TABLE 2

Bacterial content and organoleptic evaluation of pork sausage links after packaging, irradiation, and storage at 36-40° F.

Packaging material and days in storage	Irradiation dose (rep)	Bacterial count			Mean flavor score	Significance at 5% level
		Standard plate count	Total anaerobes	Putrefactive anaerobes		
Cellophane						
10	None	11×10^6	160×10^2	24×10^2	5.65	Not significant
	1×10^6	<300	23	0	4.70	Significant
17	None	29.5×10^6	17×10^2	17×10^2	5.44	Not significant
	1×10^6	1,700	0	0	3.61	Significant
24	None	48.7×10^6	1.6×10^6	130×10^2	.....	.....
	1×10^6	<300	33	23	4.90	Not significant
31	1×10^6	<300	13	2	3.85	Significant
38	1×10^6	<300	17	7	5.4	Not significant
63	1×10^6	<300	7	0	.....	.....
100	1×10^6	<300	13	0	.....	.....
Saran						
10	None	6×10^6	160×10^2	24×10^2	3.75	Significant
	1×10^6	<300	33	8	6.05	.....
17	None	3.5×10^6	2×10^2	2×10^2	1.88	Significant
	1×10^6	<300	6	0	6.16	.....
24	None	66×10^6	81×10^2	2×10^2	.....	.....
	1×10^6	<300	23	4	5.50	.....
31	1×10^6	<300	2	0	5.95	.....
38	1×10^6	.....	56	2	5.9	.....
63	1×10^6	<300	17	4	.....	.....
100	1×10^6	<300	1,800	2	.....	.....
120	1×10^6	.....	.....	.....	5.00	.....

TABLE 3

Peroxide values of pork sausage (packaged), irradiated, and stored

Days in storage	Storage temperature	Type package	Irradiation dose (rep)	Peroxide value
Patties				
49	0° F.	.....	None	8.65
	36-40° F.	.....	1×10^6	6.97
98	0° F.	.....	None	10.23
	36-40° F.	.....	1×10^6	6.77
Links				
63	36-40° F.	Cellophane	1×10^6	25.1
	36-40° F.	Saran	1×10^6	1.2
100	36-40° F.	Cellophane	1×10^6	58.2
	36-40° F.	Saran	1×10^6	2.8

for the frozen control was 5.45 (less than *like slightly* but more than *neither like nor dislike*).

By treating ground beef (hamburg) with a mixture of sodium fumarate and monosodium glutamate (0.3% and 0.5% by weight, respectively), it was possible to irradiate the beef, packed in hermetically sealed cans, at a dose level sufficient to destroy psychrophilic bacteria without causing drastic development of off-flavor. The organoleptic scores of irradiated samples held at 36-40° F. decreased as storage continued. However, until the 3-month storage period had passed, there was no significant difference between these scores and the scores for the frozen controls held at 0° F. (Table 5).

Treatment of beef sections by pumping with a solution of sodium fumarate and monosodium glutamate was unsuccessful in minimizing off-flavor caused by irradiating beef slices cut from these sections. In all cases the organoleptic scores (Table 6) indicated a significant difference between the acceptability of the frozen untreated controls stored at 0° F. and that of the chemically treated and irradiated samples stored at 36-40° F. The preference was always in favor of the control samples.

Commercial all-beef frankfurters prepared (a) with no sodium ascorbate, (b) with 0.25% sodium ascorbate, and (c) with 0.5% sodium ascorbate were irradiated with high-voltage cathode rays at dose levels of 0.25×10^6, 0.5×10^6, and 1.0×10^6 rep and held at 36-40° F. The organoleptic results indicate that 0.25% of ascorbate was necessary to prevent off-flavor at irradiation

TABLE 4

Bacterial content and organoleptic evaluation of sausage patties after irradiation and storage

Storage		Irradiation dose (rep)	Bacterial count		Mean flavor score	Significance at 5% level
Weeks	Temperature		Nature of count [1]	Organisms per gram		
7	0° F.	Control	SPC	2.0×10^6	6.00	.....
			TA	1.8×10^6		
			PA	21.0×10^2		
7	36-40° F.	1.0×10^6	SPC	<300	6.15	Not significant
			TA	7		
			PA	5		
14	0° F.	Control	SPC	.....	5.45	.....
			TA	.....		
			PA	.....		
14	36-40° F.	1.0×10^6	SPC	<300	6.83	Significant
			TA	350		
			PA	2		

[1] SPC = standard plate count; TA = total anaerobes; PA = putrefactive anaerobes.

TABLE 5

Bacterial content and organoleptic evaluation of hamburg as affected by chemical additives, irradiation and storage

Storage		Chemicals added	Irradiation dose (rep)	Bacterial count [1]			Mean flavor score	Significance at 5% level
Months	Temperature			SPC	TA	PA		
0		None	None	570 x 10^6	5900	600	5.74	
		0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	0	0	5.53	Not significant
1	0° F.	None	None				5.63	
	0° F.	0.3% Na fum + 0.5% MSG	None				6.50	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	6	1	6.84	Not significant
2	0° F.	None	None				5.62	
	0° F.	0.3% Na fum + 0.5% MSG	None				5.62	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	10	3	5.18	Not significant
3	0° F.	None	None				5.97	
	0° F.	0.3% Na fum + 0.5% MSG	None				6.13	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	21	1	4.60	Not significant
4	0° F.	None	None				6.25	
	0° F.	0.3% Na fum + 0.5% MSG	None				5.57	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	42	1	3.68	Significant

[1] SPC = standard plate count; TA = total anaerobes; PA = putrefactive anaerobes.

TABLE 6

Bacterial content and organoleptic evaluation of beef slices as affected by chemical additives, irradiation and storage

Storage		Chemicals added	Irradiation dose (rep)	Bacterial count [1]			Mean flavor score	Significance at 5% level
Weeks	Temperature			SPC	TA	PA		
0		None	None	112 x 10^6	23 x 10^6	9 x 10^6	6.01	
		0.3% Na fum + 0.5% MSG	None				5.75	Not significant
		0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	538	4	4.97	Significant
6	0° F.	None	None				6.11	
	0° F.	0.3% Na fum + 0.5% MSG	None				5.71	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	3	1	4.22	Significant
12	0° F.	None	None				6.33	
	0° F.	0.3% Na fum + 0.5% MSG	None				5.90	Not significant
	36-40° F.	0.3% Na fum + 0.5% MSG	1 x 10^6	< 300	8	1	4.93	Significant

[1] SPC = standard plate count; TA = total anaerobes; PA = putrefactive anaerobes.

TABLE 7

Bacterial content and organoleptic evaluation of frankfurters (with and without sodium ascorbate) after irradiation and storage at 36-40° F.

Storage period	Sodium ascorbate (%)	Irradiation dose (rep)	Bacterial count [1]			Mean flavor score	Significance at 5% level
			SPC	TA	PA		
Initial	None	None	76 x 10^3	3150	1350	6.20	
	None	0.25 x 10^6	340	3	0	4.80	Significant
	0.25%	0.25 x 10^6				6.40	Not significant
	0.5%	0.25 x 10^6				6.40	Not significant
Initial	None	None				5.37	
	None	0.5 x 10^6	< 300	3	0	4.05	Significant
	0.25%	0.5 x 10^6				5.84	Not significant
	0.5%	0.5 x 10^6				6.00	Not significant
Initial	None	None				6.74	
	None	1 x 10^6	485	13	3	3.26	Significant
	0.25%	1 x 10^6				5.58	Significant
	0.5%	1 x 10^6				6.32	Not significant
1 month	None	None	67 x 10^6	8300	4700		
	None	0.25 x 10^6	< 300	17	9		
1 month	None	None				6.00	
	None	0.5 x 10^6	< 300	2	2	4.85	Significant
	0.25%	0.5 x 10^6				5.50	Not significant
1 month	None	None				6.90	
	None	1 x 10^6	< 300	8	0	3.10	Significant
	0.5%	1 x 10^6				4.30	Significant
2 months	None	None	50 x 10^6	67 x 10^6	49 x 10^6		
	None	0.25 x 10^6	> 300 x 10^6	9	2	5.25	
	0.25%	0.25 x 10^6				5.66	
2 months	None	0.5 x 10^6	< 300	1	1		
	0.25%	0.5 x 10^6				6.33	
	0.5%	0.5 x 10^6				5.91	
2 months	None	1 x 10^6	< 300	5	2		
3 months	None	0.25 x 10^6	6.5 x 10^6	430	0		
	None	0.5 x 10^6	< 300	10	3		
	None	1 x 10^6	< 300	79	25		

[1] SPC = standard plate count; TA = total anaerobes; PA = putrefactive anaerobes.

levels of 0.25×10^6 and 0.5×10^6 rep (Table 7). When the dose level was 1.0×10^6 rep, off-flavors were obviated by treatment of the meat with sodium ascorbate in a concentration of 0.5%.

At the end of a 2-month storage period, unirradiated control samples of frankfurters had spoiled because of the growth of molds and bacteria, whereas none of the samples irradiated at any dose level had decomposed in this manner after a 3-month storage period (Table 7).

CONCLUSIONS

It was possible to extend the storage life of spinach held at 36-40° F. by preliminary blanching, packing in an hermetically sealed container, and irradiating with high-voltage cathode rays at a dose level of 1.5×10^6 rep.

Fresh pork sausage links packed in saran under vacuum and irradiated with 1.0×10^6 rep proved to be edible after storage for 120 days at 36-40° F.

Sausage patties retained better organoleptic qualities at the end of 14 weeks of storage when packed in hermetically sealed cans, irradiated with 1.0×10^6 rep, and stored at 36-40° F. than when similarly packed and stored at 0° F. without irradiation treatment.

The storage life of ground beef at 36-40° F. was extended to approximately 12 weeks by packing the beef in hermetically sealed containers and irradiating it at a dose level of 1.0×10^6 rep. However, it was necessary to add 0.3% of sodium fumarate and 0.5% of monosodium glutamate to this product to obviate irradiation off-flavor.

An attempt to prevent irradiation off-flavor in beef slices by pumping pieces of beef with a solution of sodium fumarate and monosodium glutamate was unsuccessful.

The deterioration, through microbial action, of commercial all-beef frankfurters held at 36-40° F. could be delayed to some extent by irradiation at dose levels as low as 0.25×10^6 rep. Irradiation with 1.0×10^6 rep prevented for at least 3 months the deterioration of frankfurters held at 36-40° F. However, to prevent irradiation off-flavor, even with low irradiation doses, it was necessary to incorporate 0.25% or more of sodium ascorbate in the product.

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Influences of Ionizing Radiations on the Protein Components of Selected Foods[a,b]

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An objective procedure, based on electrophoretic analysis, for determining radiation induced changes in casein and egg albumen is described. The method provides a means of evaluating the effectiveness of free radical acceptors in shielding proteins against undesirable radiation-induced changes.

Radiation sterilization of foods is the first new basic method of food preservation since Appert's discovery of canning. Employing ionizing radiations it is possible to kill the most resistant microorganisms with a negligible temperature rise. The advantages of such a process are obvious. Potentially it is possible to preserve fresh foods with the retention of the desired qualities of freshness. Side effects, chemical reactions resulting in off-flavors and off-odors, are the principal obstacles to commercial application of this process *(3)*. These changes, as well as other problems involved in radiation processing, are being studied extensively at the present time. Commercial application must await the outcome of such research. When practical methods have been worked out for sterilization of foods by irradiation, a revolution may be in store for the food industry.

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Some low moisture foods, such as cereals *(8)*, dried fruits *(15)*, and spices *(14)*, can be irradiated without apparent alterations. However, the changes which occur in many foods are quite pronounced. Meat products *(12)*, fish *(10)*, dairy products *(4, 6)*, and poultry products *(7)* have been found to undergo undesirable changes when exposed to ionizing radiations. Because high protein foods such as meat, milk, and eggs exhibit obvious changes it was believed that much of the radiation effect is on the protein component of foods.

The radiation-induced alterations in foods, as well as methods for their control have been studied extensively *(5, 12, 13)*. The methods employed for detecting changes have been mostly organoleptic. This is an important consideration from the standpoint of food acceptability. However, it was believed that objective methods for determining radiation-induced changes would be desirable. The absence of obvious changes, those which can be detected by organoleptic methods, does not necessarily indicate the absence of subtle changes which might have important dietary considerations.

The investigation herein reported relates to some of the influences of ionizing radiations on purified casein and egg albumen when these proteins are irradiated in aqueous solution. An objective procedure is advanced for determining these radiation-induced changes as well as for evaluating agents protective against such alterations.

EXPERIMENTAL PROCEDURE

Commercially prepared casein and egg albumen were used in these experiments. Both proteins were irradiated in 2% aqueous solution at pH 7.0. Irradiation was accomplished with a 4 m.e.v. cathode ray produced by a linear electron accelerator. Molecular changes occurring in casein and albumen as a result of the action of ionizing radiations were determined by several methods.

The liberation of sulfhydryl groups. Sulfhydryl groups were assayed by the Shinohara-Kilpatrick method for the nitroprusside test *(2)*. A standard curve was prepared using cysteine hydrochloride, and the sulfhydryl determinations of the unknown were reported as micrograms per ml. of cysteine hydrochloride. Nonirradiated solutions of casein and egg albumen were used as controls.

The effectiveness of ascorbic acid in protecting the protein solutions from the action of cathode rays on the dithio linkages was determined by adding 0.5 mg. of the vitamin per ml. of sample. The protein solutions were then irradiated and assayed by the procedure given above.

A dose of 1.5×10^6 rep was applied to the proteins since this level of radiation would be required for complete sterilization.

Changes in the relative viscosity of protein solutions. Viscosity measurements were made at 86° F. (30° C.) using Cannon-Fenske modified Ostwalt viscosimeters having a water flow time of 47.0 seconds. Five ml. of solution were used in all determinations. Nonirradiated solutions were used as controls.

The protective effect of ascorbic acid was determined by adding 0.5 mg. of ascorbic acid per ml. of the solutions before exposure to the cathode rays. The viscosity determinations were made as described above.

The effects of various dose levels of cathode rays (0.5×10^6, 1.0×10^6, and 1.5×10^6 rep) on the relative viscosities of casein and egg albumen were determined.

Changes in the rate of reaction of trypsin on casein and egg albumen. The effects of cathode rays on the reaction rate of trypsin on casein and egg albumen were studied. Two percent aqueous solutions of the proteins (pH 7.0) and 0.5% solution of commercial trypsin in phosphate buffer (pH 7.0) were used. Samples of the proteins and the enzyme were exposed separately to 1.5×10^6 rep doses of cathode rays. One ml. of the enzyme preparation was then added to 10 ml. of protein solution, mixed thoroughly, and allowed to react at 86° F. (30° C.). The reaction rate was followed by the determination of amino nitrogen after 0, 30, 60, 90, and 120 minute reaction times. All the possible combinations of treated and control solutions were assayed.

Amino nitrogen was determined by the formol titration method. The method described in the official methods of the AOAC *(11)* was modified to the following: Two ml. of sample were added to 8 ml. of distilled water and the mixture neutralized to phenolphthalein with NaOH. Five ml. of freshly neutralized 40% formaldehyde were added and the mixture was titrated to a pink end point with .05 N NaOH. Phenolphthalein was used as the indicator.

Changes in the electrophoretic mobilities and patterns of protein solutions. The effects of cathode rays on the electrophoretic behavior of casein and egg albumen were determined by irradiating aqueous solutions of these proteins. Doses of 1.5×10^6 rep were used.

The irradiated samples and nonirradiated controls were prepared for electrophoretic analysis as follows: (a) The solutions were diluted 1:1 with phosphate buffer to reduce the concentrations to 1%. (b) The protein solutions were transferred to a dialysis bag and dialysed in 750 ml. of the electrophoresis buffer for 24 hours at 40° F. (4.5° C.). (c) The solutions were transferred to a 2 ml. electrophoresis cell.

The patterns and mobilities were determined by a Tiselius Electrophoresis Apparatus (Model 38). The patterns were photographed and the mobilities calculated from measurements made on the negatives.

All electrophoretic studies were conducted at a field strength of 4.95 volt/cm. in phosphate buffer with an ionic strength of 0.1 and a pH of 8.4.

The protective effect of ascorbic acid was determined. The procedure was as given above.

All experimental data were obtained in triplicate. When greater reproducibility seemed desirable, additional replicates were obtained.

RESULTS

The liberation of sulfhydryl groups. The effects of cathode rays on the sulfhydryl activity of casein and egg albumen in aqueous solution are summarized in Figure 1. Irradiation of the solution caused a substantial increase in free sulfhydryl groups with no increase in free amino nitrogen.

The albumen solution shows a higher sulfhydryl content than

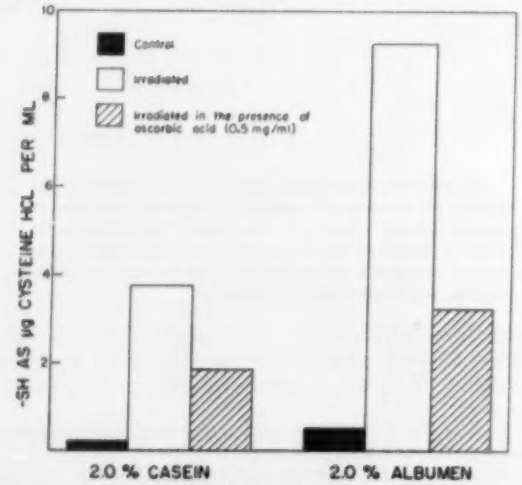


Figure 1. The liberation of sulfhydryl groups in irradiated (1.5×10^6 rep) protein solutions and the protective effect of ascorbic acid.

proportionate sulfhydryl increase of irradiated solutions over the controls is about the same.

Ascorbic acid appears to offer greater radiation protection to albumen than to casein. Radiation in the presence of the vitamin decreased sulfhydryl production by 68% in albumen and by 50% in casein.

Changes in the relative viscosity of protein solutions. A summary of the effects of cathode rays on the relative viscosity of casein in aqueous solution is given in Figure 2. A the casein due to its greater sulfur content. In both cases the radiation dose of 0.5×10^6 rep resulted in a slight decrease in relative viscosity. As the dose was increased above this level, the viscosity increased. At radiation levels in the range of 1.0×10^6 to 1.5×10^6 rep, the relative viscosity increase apparently follows a straight line.

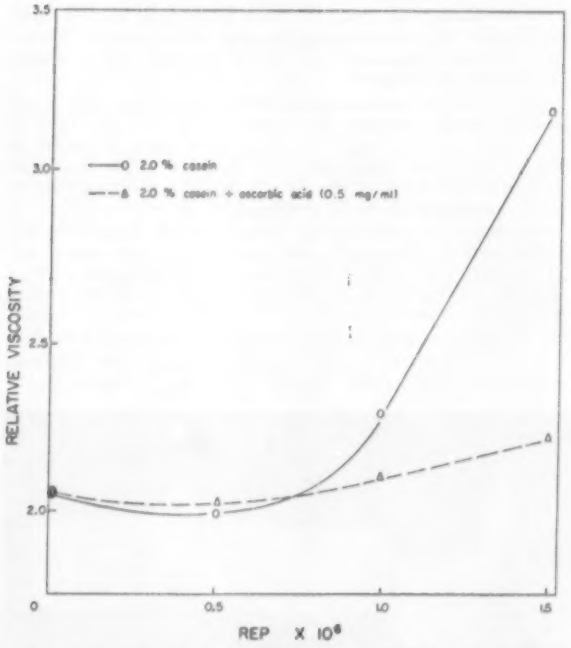


Figure 2. The effects of irradiation on the relative viscosity of a solution of casein, and the protective effect of ascorbic acid.

Only slight changes in relative viscosity occurred when casein was irradiated in the presence of ascorbic acid. The changes which did occur followed the same pattern as those in the unprotected protein.

A summary of the viscosity changes of the egg albumen solution is given in Figure 3. Albumen does not show a reduction in relative viscosity at lower radiation doses. Its viscosity increased directly with the radiation dose and appeared to be a straight line function throughout the entire dose range used in these experiments.

Ascorbic acid reduced the rate of viscosity increase, but the changes which did occur followed the same general pattern as in the unprotected protein solution.

Changes in the reaction rate of trypsin with casein and egg albumen. The effects of irradiation on the reaction rate of trypsin on casein and egg albumen are summarized in Figure 4 and Figure 5, respectively. Radiation by cathode rays altered the protein molecules in such a way that they are more readily hydrolyzed by trypsin. A radiation dose of 1.5×10^6 rep reduced the activity of the 0.5 percent aqueous solution of trypsin but it did not completely inactivate the enzyme.

Changes in the electrophoretic mobilities and patterns of protein solution. The changes in the electrophoretic behavior of

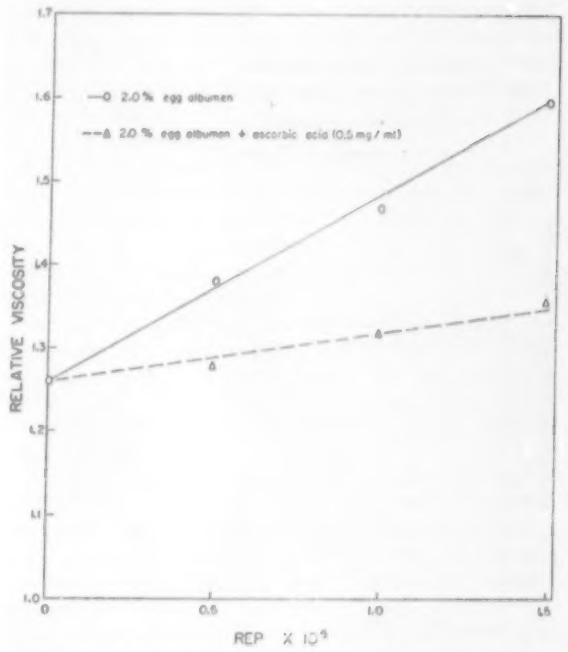


Figure 3. The effects of irradiation on the viscosity of a solution of egg albumen and the protective effect of ascorbic acid.

casein by cathode ray irradiation are shown in Figure 6 and Table 1. Figure 6a illustrates the pattern obtained in the control solution. Two components are apparent which have been designated (l. to r.) alpha and beta casein *(9)*. The mobilities of the two components are given in Table 1.

After exposure to cathode rays the pattern of casein appears as a single component (Figure 6b) which migrates at a rate much slower than either of the components in the control. The resolution obtained in this pattern was not very satisfactory due to some change in the optical properties of the casein during irradiation.

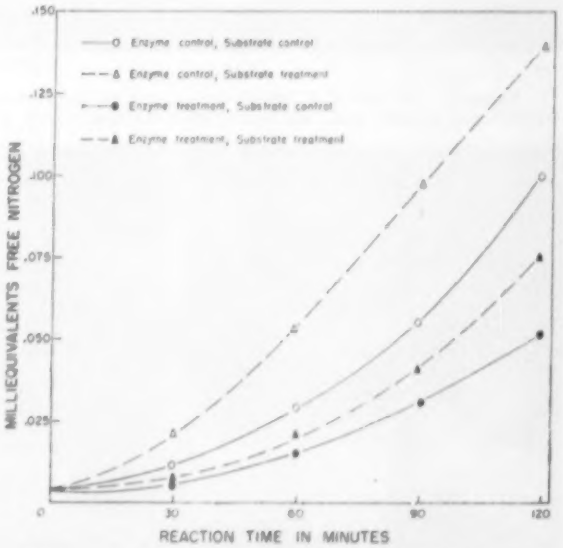

MILLIEQUIVALENTS FREE NITROGEN
REACTION TIME IN MINUTES
O Enzyme control, Substrate control
Δ Enzyme control, Substrate treatment
● Enzyme treatment, Substrate control
▲ Enzyme treatment, Substrate treatment

Fig. 4. The effects of irradiation (1.5×10^6 rep) on the reaction rate of trypsin with casein.

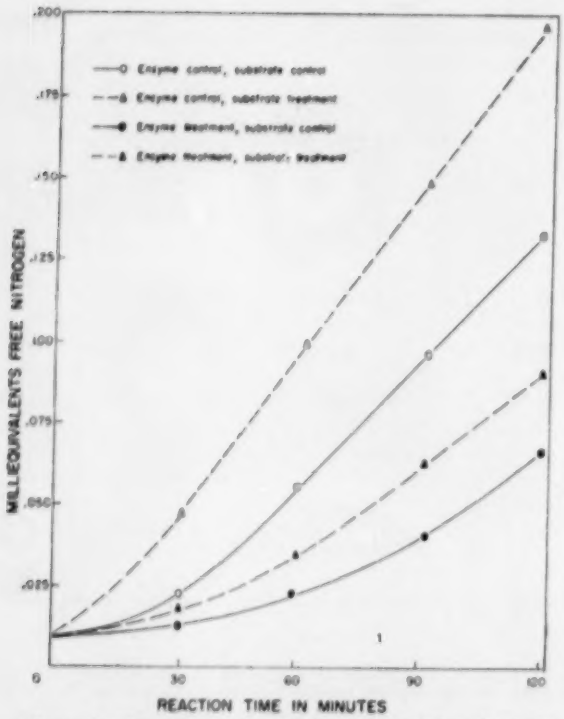


Figure 5. The effect of irradiation (1.5 × 10^5 rep) on the reaction rate of trypsin with egg albumen.

TABLE 1

The effects of irradiation on the electrophoresis mobilities of casein. The protective effect of ascorbic acid.
pH = 8.4
Ionic strength = 0.1
Field strength = 4.95 volt/cm.

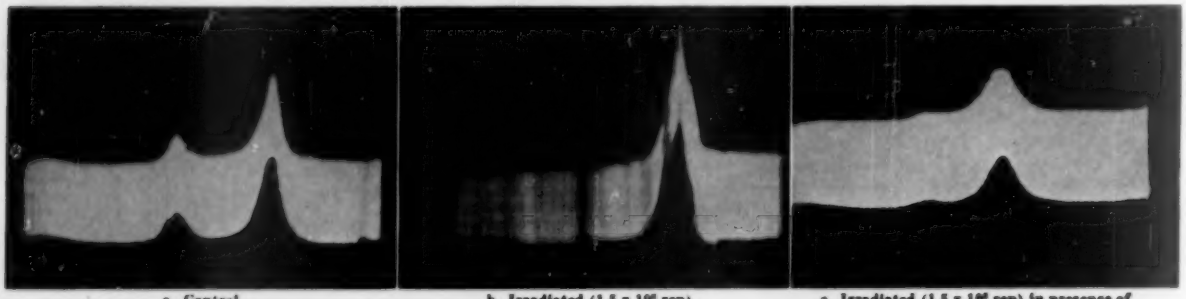
Casein treatment	Mobilities x 10^5 (cm.^{2} volt^{-1} sec.$^{-1}$)		
	Alpha component	Beta component	Unidentified component
Control	4.10	2.21	
1.5 x 10^6 rep			1.14
1.5 x 10^6 rep in presence of ascorbic acid (0.5 mg./ml.)	3.72	1.87	

When casein was irradiated in the presence of ascorbic acid, its pattern more nearly resembled that of the control (Figure 6c). The two components are present, but their rate of migration is reduced (Table 1).

The effects of cathode rays on the electrophoretic pattern and mobility of egg albumen are shown in Figure 7 and Table 2. The pattern of the control solution of albumen is shown in Figure 7a. Three components are apparent which have been designated (l. to r.) as A_1, A_2 and A_3 *(9)*. The mobilities of these components are listed in Table 2.

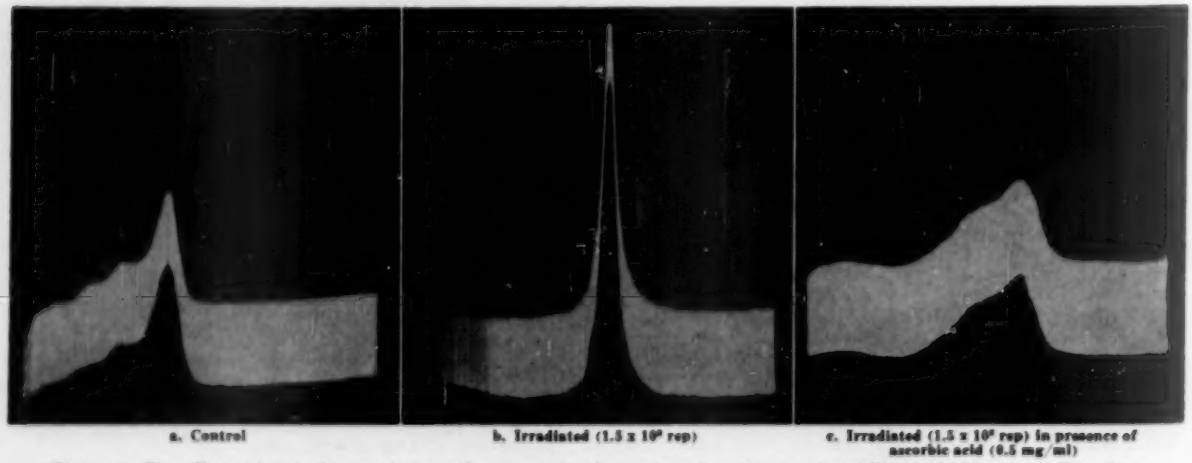
Irradiation of the albumen solution results in a much different pattern (Figure 7b) with apparently a single component at this pH. The mobility of this component falls about midway between components A_2 and A_3 in the pattern of the control (Table 2).

Albumen irradiated in the presence of ascorbic acid exhibits a pattern (Figure 7c) similar to that of the control. All three components were visible, although A_1 is very obscure in the



a. Control | b. Irradiated (1.5 x 10^6 rep) | c. Irradiated (1.5 x 10^6 rep) in presence of ascorbic acid (0.5 mg/ml)

Figure 6. The effects of cathode rays (1.5 x 10^6 rep) on the electrophoresis pattern and mobilities of casein (1%). The protective effect of ascorbic acid. pH = 8.4; Ionic strength = 0.1; Field strength = 4.95 volt/cm.



a. Control | b. Irradiated (1.5 x 10^6 rep) | c. Irradiated (1.5 x 10^6 rep) in presence of ascorbic acid (0.5 mg/ml)

Figure 7. The effects of cathode rays (1.5 x 10^6 rep) on the electrophoresis pattern and mobilities of albumen (1%). The protective effect of ascorbic acid. pH = 8.4; Ionic strength = 0.1; Field strength = 4.95 volt/cm.

TABLE 2

The effects of irradiation on the eleptrophoresis mobilities of egg albumen (1%). The protective effect of ascorbic acid.

pH = 8.4
Ionic strength = 0.1
Field strength = 4.95 volt/cm.

Albumen treatment	Mobilities x 10^5 (cm.^{2} volt^{-1} sec.$^{-1}$)			
	Component A1	Component A2	Component A3	Unidentified component
Control	4.98	2.18	0.933	1.04
1.5 x 10^6 rep				
1.5 x 10^6 rep in presence of ascorbic acid (0.5 mg./ml.)	4.12	2.01	0.884	

photograph. The mobilities of the three components (Table 2) are at a slightly slower rate than in the control.

DISCUSSION

The effects of cathode rays on aqueous solutions of casein and egg albumen indicate that there is a change in both protein molecules. The pattern of alteration differs in the two proteins; however, the increase in free sulfhydryl groups demonstrates conclusively that molecular rearrangement does occur. Since these molecular changes did not result in any increase in amino nitrogen, it is believed that the peptide linkages are not attacked under the conditions of these experiments. The sulfur linkages are very definitely the site of a large share of the radiation effect. Hydrogen bond linkages also are undoubtedly broken.

Effect on casein. The course which the molecular changes follow is not the same in the two proteins studied. In casein the sequence of changes appears to be as follows. A splitting of some of the molecules occurs at cathode ray doses of about 0.5 x 10^6 rep. This is indicated by a decrease in relative viscosity which, under the experimental conditions, could result only from a decrease in molecular size. The molecular splitting is followed by polymerization of fractions which result in a relative viscosity increase. Polymerization progresses with the radiation dose until visible coagulation of the protein occurs. This point was reached at radiation doses slightly above 1.5 x 10^6 rep. Above this level the viscosity could no longer be measured because of coagulation.

The pattern of casein denaturation outlined above is similar to that which has been obesrved in heat denaturation of this protein *(9)*. With heat the molecules split, polymerize, and eventually coagulate. The viscosity alterations follow a course identical to that described above.

Further evidence in support of the molecular changes described may be obtained by comparing the electrophoretic patterns of the control and irradiated solutions of casein. Irradiation results in an entirely new electrophoretic component which is distinctly different from the alpha and beta components of the nonirradiated casein. It differs decidedly in mobility and in pattern. At radiation doses of 1.5 x 10^6 rep the casein has been changed to a form with molecular properties which differ from the original protein.

Effect on egg albumen. Cathode ray irradiation produces molecular changes in albumen which differ from those observed in casein. Albumen molecules apparently were not split by radiation. The globular molecules appear to change slowly, giving rise to an asymmetrical molecule which causes an increase in relative viscosity. The molecular rearrangement progressed with the radiation dose, following a straight line over the entire dose range.

From this gradual increase in relative viscosity one would conclude that polymerization is not occurring, at least not at a very great rate. The molecular change appears to be a transformation of the globular form to an asymmerical molecule which remains unassociated at the radiation levels employed.

Radiation denaturation of egg albumen closely resembles that produced by heat. In heat denaturation the globular molecules are changed to give asymmetrical forms. These then polymerize and coagulation results *(9)*. These changes are demonstrated by an increase in relative viscosity.

The electrophoretic behavior of irradiated albumen substantiates the changes which have been described. The pattern produced by irradiated albumen shows a single component which is decidedly different in pattern and mobility from any of the components in non-irradiated albumen.

Cathode ray irradiation of an aqueous solution of egg albumen at a level of 1.5 x 10^6 rep produces molecular rearrangements which change the physical and chemical properties of the protein.

Further studies are required on the degradation products formed by the action of ionizing radiations on proteins. Determinations of their molecular weights and their chemical and physical properties are indicated in order to have a better understanding of the action of ionizing radiations on protein substances.

The significance of enzyme reaction rates. The increased rates of enzymatic hydrolysis of irradiated casein and albumen are further indications that ionization of the bonds by radiation caused an opening of the molecules. Increased enzyme reaction rates have previously been observed following the exposure of proteins to denaturing substances. The accelerated hydrolysis by the proteolytic enzymes is apparently due to changes in the molecules which render points of attack more accessible and/or more vulnerable. This effect is produced in casein and egg albumen by the action of cathode rays.

The effects of radiation on the activity of trypsin have been studied previously *(1)*. The activity of irradiated trypsin solutions indicated that this enzyme is quite radioresistant even *in vitro* when irradiated under the conditions of these experiments. Cathode ray doses sufficient to sterilize many food substances failed to inactivate dilute aqueous solutions of trypsin. The enzyme exhibits an even greater resistance in natural food substances.

Radiation sterilization might bring about a more rapid deterioration of food substances by rendering proteins more susceptible to hydrolysis by proteolytic enzymes, while at the same time failing to inactivate these enzymes. Whenever the naturally occurring proteolytic enzymes are not inactivated and their reaction rates are accelerated, a more rapid breakdown of the

food may result. Such activity could be responsible for some of the flavor changes which have been attributed to side reactions. Further experimentation is required to determine if accelerated proteolytic activity resulting from radiation sterilization might be responsible for some of the flavor changes which occur in irradiated foods.

The protective effect of ascorbic acid. Ascorbic acid reduced the effects of cathode rays on protein solutions. A part of the energy of radiation is expended on ascorbic acid, thus reducing the protein changes.

Further study on the mode of action of free radical acceptors is required to determine the molecular structure involved in the protective reaction. Once this information has been obtained, substances with greater protective properties may be found. Free radical acceptors more effective than ascorbic acid will be required before side reactions can be reduced sufficiently to make radiation sterilization of foods practical.

The determination of changes in electrophoretic behavior of proteins provides an objective method for determining the effectiveness of protective substances. By studying electrophoretic patterns and mobilities of proteins which have been irradiated in the presence of different protective agents, it is possible to determine which agent affords the best protection against changes in the proteins. Such a method would provide a more reliable evaluation of free radical acceptors than could be obtained by organoleptic methods.

SUMMARY

Some of the effects of radiation on aqueous solutions of purified casein and egg albumen were determined.

A splitting of casein molecules into smaller fractions occurred when the purified protein was irradiated in aqueous solution. Further irradiation caused the association of these molecular fractions until complete coagulation took place. The effects were similar to those produced by heat.

Molecules of egg albumen were transformed from a globular form to an asymmetrical molecule when the purified protein was irradiated in aqueous solution. Molecular splitting apparently did not occur; however association of the transformed molecules resulted in coagulation when irradiation was prolonged. The results of radiation resembled those changes induced in the protein by heat.

The trypsin hydrolysis rates of casein and egg albumen were increased when the proteins were irradiated. This increased susceptibility to the action of proteolytic enzymes, along with the radio-resistance of such enzymes in foods, indicated that some of the changes in irradiated foods might result from the accelerated activity of naturally occurring proteolytic enzymes on the activated substrates.

All of the observed effects were reduced when the proteins were irradiated in the presence of ascorbic acid.

An objective method for determining molecular changes which occur in proteins during irradiation is provided by electrophoretic analysis. Studies of the comparative changes in electrophoresis patterns and mobilities provide an objective means of evaluating the effectiveness of free radical acceptors.

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More Miles per Pound of Food[a]

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(Manuscript received July 27, 1955)

Fuel and ammunition are not the only factors limiting the operational endurance of Navy fighting ships at sea. Food and human endurance rival these in importance and must be given at least equal consideration.

Food supplies and the morale and operating efficiency of the men who consume them are closely interrelated. If food is in short supply or poor in quality, morale is poor. If morale is poor for some reason, the men often lose their appetites and less food is consumed and operating efficiency becomes lower.

Both the Kaiser's and Hitler's admirals realized the importance of food in the maintenance of morale and human endurance. The submariner was always the best fed man in the German Armed Forces. That was one reason why the Submarine Force was the most efficient Naval Force the Germans had. In our own Navy, the submariner is a high caliber volunteer, and one of the main reasons for his being a volunteer is the fine food for which submarines are famous.

The problem as developed by the Commissary Research Division, U. S. Naval Supply Research and Development Facility, is *"to extend the ration endurance of Navy ships, particularly submarines, while maintaining or improving the high acceptability and morale-raising qualities of the food."* (Figure 1.) The problem is

Figure 1. Dry stores for one submarine.

not as simple as it appears on the surface. It is true, you can remove some of the inedible waste, dehydrate, concentrate, freeze, compress, precook, mold, prefabricate, reduce storage loss, and pack food in the most efficient space-saving packages—but this is only the start in increasing ration endurance of ships.

The institutional feeding technologist takes over where the food technologist leaves off. He reduces: preparation waste, cooking losses, tray waste, leftovers. He must develop: recipes for using the new foods, efficient food handling methods, proper portion sizes, the best cooking temperatures, efficient food service techniques, and efficient coordinated galley operation.

The institutional feeding specialist in turn leans heavily on the equipment specialist to provide: (1) storage spaces that will hold raw food and leftovers without spoilage loss until they are used, and shelving which will allow storage of foodstuffs with a minimum of unused air space; (2) accurate temperature controls; (3) most desirable shape and capacity—ovens, grills, steam-jacketed kettles, deep fat fryers, and pressure cookers; (4) pots and pans of the proper heat conductivity, size, shape, and resistance to corrosion; and (5) food holding devices which will maintain prepared food at the proper temperature and humidity until it is served.

It is difficult to assess the comparative importance of the efforts of the food technologist, institutional feeding technologist, and commissary equipment specialist in obtaining more miles per pound of food placed aboard ship. However, let us examine their contributions in the light of submarine feeding.

FOOD TECHNOLOGIST

The food technologist makes his contribution to the submariner by removing the waste, peel, rind, skin, shell, water, grounds, bone, cores, pits, stems, pods, and unusable fat (Figure 2). He compresses the food into less space, molds it into a square storage space-saving shape, packages it in the best packaging material, reduces storage losses by chemical dips, irradiation, ultraviolet treatment, ozone, anti-ripening agents, anti-sprouting agents, and establishment of optimum storage temperatures and humidity.

It will be of interest to note what the food technologist, among many other things, has done.

The food technologist has taken the shell egg, which occupies about one cubic foot per 75 rations, removed

Figure 2. Waste in foreground should be left ashore for efficient frozen space utilization.

[a] Presented at the Fifteenth Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 14, 1955.

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the shells and frozen them in round 10-lb. cans. This meant he could get 150 rations into a cubic foot. He froze the eggs in square-cornered cans and obtained 220 rations in 1 cubic foot of space. Then he removed the water from the eggs and obtained 270 rations in 1 cubic foot. Not only that, but by buying judiciously and using commercial cold storage for the frozen eggs and government storage for the dried eggs, he has made it cheaper for the Navy to use these products during 10 months of the year.

When the food technologist took the potato to the laboratory, he found that the Navy cook used 1.32 cu. ft. of fresh potatoes to feed 100 men. He tried canning the potatoes and found that while he reduced labor and improved keeping qualities, he reduced space requirements but little, so he tried refrigerating peeled potatoes. Here again he saved labor but space savings were negligible and weight reduction was on the order of 15%. This left only dehydration. By dicing the potato and then dehydrating, the food technologist could get 100 rations of potato in .4 cu. ft., and by granulating the potato he could get 100 rations in less than .2 cu. ft. Of course, square-cornered cans would save even more space.

Similarly, you can trace the food technologists' progress in oranges—from fresh oranges to concentrates of various strengths to the puff dried orange crystals we have today. Look at another product, tomatoes. You can trace the removal of water in tomatoes from fresh tomatoes, to canned whole, juice, puree, paste, juice concentrates, and finally to drum-dried, spray-dried, and puff-dried tomato powders or flakes.

It is not the purpose of this paper to trace the reduction of space needed for the various food products, but it can be safely said that at present the food technologist, alone, can increase the ration endurance of Navy ships by 25-30% without substantially increasing total cost or reducing acceptability.

INSTITUTIONAL FEEDING TECHNOLOGIST

The institutional feeding technologist plays a vital part in increasing the ration endurance of ships by developing procedures for properly preparing new foods for introduction into the Navy feeding system and by improving the present methods for using the foods already in the system. He must reduce preparation, cooking and service losses, and decrease tray waste and leftovers. A ship that loses edible food through waste, loses operational endurance the same as a ship that accidentally dumps an oil tank into the sea.

The institutional feeding technologist starts his food saving before he goes to sea. When he orders his provisions, he procures only those which are most likely to be eaten. This means he must have a keen appreciation of submarine life. Eating patterns change as lack of exercise, boredom, lack of night and day, and nervous tension push the average submariner away from the table. Roast pork and mashed potato may be a treat to him during the first week at sea but at the end of six weeks he might not touch them. He eats more and more between meals. Fresh, tart, and spicy foods become more intriguing to him than bland foods.

When he loads the ship, and when he sets up his menus, the institutional feeding specialist must plan to use those foods which will spoil first and those foods which will have high initial acceptability but lower acceptability later in the trip. As the storage boxes are usually packed as solid as possible, the submariner must eat his way into the boxes or move much material; thus, it takes prior planning to serve a varied diet.

After he gets to sea, the feeding technologist really has problems. Men are going on and off shifts day and night. Some of the crew are always sleeping. When shifts change other than at mealtime, both shifts want something to eat; sandwiches, coffee, soup, etc. The cook never knows how many men are going to show up for dinner or how much they will eat. He has to "feel" his ship so as to make up enough food but not too much. He also has to be skilled in knowing how acceptability of foods changes as the trip goes on. A food may be prepared in a 70-ration quantity to provide for the acceptability existent on the 7th day and in a 30-ration quantity at the acceptability level existent on the 30th day.

Other ways that the institutional feeding specialist saves on food are as follows:

1. Selecting those recipes and preparing them so as to have a high level of acceptability and cut down on tray waste.

2. Scheduling galley operations so as to have the food ready for the meal at the time it is at maximum acceptability.

3. Exercising care that a minimum of edible food is lost as peel and trim in undrained or unrinsed cans, unused surplus fluid from canned foods, etc.

4. Making sure that leftovers are used quickly and tastefully.

5. Making certain that foods are cooked at temperatures and under conditions which preserve a maximum of the food weight and value.

6. Make portion sizes in accordance with the appetites of the men and encourage them to take no more than they will eat.

Much of this research, developed by the institutional feeding technologist in his laboratory, can be lost when it is transferred to the feeding technician or cook. Constant training and supervision are necessary to get maximum benefits from this research. Skill in the cook's position can add at least 20% to the average submarine's ration endurance.

COMMISSARY EQUIPMENT SPECIALIST

Working closely with the food technologist and institutional feeding specialist is the commissary equipment specialist who can do much to make their work easier and more fruitful. In general, he seeks to make the equipment as efficient, automatic, foolproof and trouble free as possible by applying the lastest developments in human, industrial, mechanical, electronic, and other engineering.

Working with the food technologist, he calculates, for

example, that if storeroom shelving were adjustable in 5-inch increments, instead of the present 6-inch increments, and if the No. 10 can was dispensed with in favor of the No. 2, 2½, 300, 303, No. 3 cylinder, and 5-gallon, less space would be wasted between the can tops and the next shelf (Figure 3). At least 10% more food can

Figure 3. Carefully loaded submarine dry storeroom showing shelf space lost by use of No. 10 cans.

be placed in the average submarine dry storeroom by adopting this expedient.

The average cook in the Navy loses about 35% of his roast beef in the oven. This is due to uneven oven temperatures, uncertain temperature controls, too high oven temperature, and opening the oven frequently to see how the meat is cooking. The equipment specialist can cut this meat loss down to 15% (Figure 4) by providing well regulated, even heat in the ovens, a meat thermometer with the indicating dial outside the oven and connections into the controls so as to shut off the oven

Figure 4. Roast beef cooked at 15 percent roasting loss.

and give alarm when the meat is done. If applied throughout the Navy, this could mean a savings of about $400,000 per year on roast beef alone.

Many of a cook's poor work habits and much of his improperly cooked food are due to the need for speed in cooking and to his crowded work spaces. One submarine cook prepares three meals a day with three sitting shifts to each meal, plus soup and sandwiches in the afternoon. The baking is done at night by another cook. All of this cooking for 50-100 men is done in a 6 x 9-foot space, which is smaller than most home kitchens where food for 2 to 5 people is prepared.

The equipment specialist helps the cook by reducing cooking times, decreasing the physical movement necessary, making working conditions less tiring, arranging equipment in most efficient order and position, and by making equipment as automatic as possible so that it doesn't have to be constantly tended. This pays off as less food is wasted, meals are better, morale is raised, and the well-trained cooks are more interested in staying in the Navy.

It is difficult to measure exactly how much the equipment specialist increases ration endurance but it is safe to assume that by acting in concert, with the food technologist and the feeding technologist, the three specialists could increase the ration endurance of submarines by 50%.

FEEDING IS AN IMPORTANT ELEMENT IN OPERATIONS

It can be seen from the preceding observations that solving feeding problems is not a simple task. When a new food is to be introduced into the Navy feeding system, the factors of recipes to be used, equipment to prepare the food, and caliber of the personnel to prepare the product must be considered and brought into balance. Similarly, if a new preparation procedure or new piece of equipment is up for consideration, the other factors must integrate properly or the idea is doomed to failure.

If ration endurance of Navy ships is to be increased, the foods must be tailored for the job, the commissary equipment must be the most efficient that can be provided, the techniques to be used must be carefully tested, and above all the commissary personnel must be properly indoctrinated in feeding operations and have the same degree of training as the torpedo and diving crews. Feeding is as much a wartime operation as is shooting a gun, laying a mine, or dodging a torpedo.

A Proposed Method for Converting Hunter Color Difference Meter Readings to Munsell Hue, Value and Chroma Renotations Corrected for Munsell Value[a]

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(Manuscript received June 21, 1955)

A method for converting Hunter Color Difference Meter readings to Munsell terms is described. The method is shown to increase the accuracy of interpretations of color data obtained on tomato juice samples during processing.

Many workers have used color indices for evaluating the color of tomatoes and tomato products *(3, 4, 5, 6, 7, 8, 9, 10, 15, 16, 18, 21, 22, 23)*. These indices serve a very useful purpose in many cases. However, the interpretation of color changes in terms of the three dimensions (hue, value and chroma) of the Munsell color system, is not always possible from these indices.

Furthermore, in a study of the effect of processing methods on the color of tomato juice, it was found that in converting Hunter Color Difference Meter readings to Munsell hue, value and chroma renotations that the method used by Younkin *(24, 25)* was not entirely satisfactory due to the large changes in Munsell value renotations which took place during processing. Therefore, a method is proposed to correct hue and chroma renotations for Munsell value. The method should prove useful in reducing errors in evaluating color changes produced during the processing of tomato juice in terms of the Munsell color system.

REVIEW OF THE LITERATURE

I.C.I. system. The International Commission on Illumination in 1931 recommended the standard observer for color standardization that is widely used today *(14)*. Hardy *(11)* has explained the establishment of and necessity for a standard observer. In the I. C. I. method of color notations, instrument readings are reduced directly into terms of the standard observer and coordinate systems of colorimetry adopted in 1931. The data are expressed as the absolute (X, Y, Z) and fractional (x, y, z) amounts of 3 imaginary red, green, and blue lights necessary for an imaginary standard observer to match a given sample under a given illuminant *(20)*.

Conversion to Munsell Color System. The Munsell method of color notation may be used indirectly by converting I. C. I. notations to Munsell notations. The relations of Munsell hue, value, and chroma have been studied in I. C. I. terms and data are available for converting from one to the other *(20)*. It is also possible to convert Hunter L, a and b readings to I. C. I. terms (X, Y, Z). By appropriate calculations and graphical methods, the I. C. I. values may then be converted to Munsell renotations as published by Newhall, Nickerson and Judd *(19)*. Younkin gives tables *(24)* for plotting appropriate Munsell renotation loci in terms of Hunter a_L and b_L values.

These data as presented by Younkin may be calculated in the following manner:

The chromaticity of the color is usually indicated by chromaticity coordinates (x, y, z) computed from the tristimulus values (X, Y, Z) as fractions of their total, thus *(14)*:

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

Nickerson *(20)* has published data which give I. C. I. (Y) equivalents for the recommended Munsell value scale. Since the data presented are in terms of Y_r (%) (which are in percent relative to M_gO), it is necessary to divide the Y_r (%) by 100 to obtain Y for any specified Munsell value.

Loci of constant hue and constant chroma in I. C. I. (x, y) — coordinates for I. C. I. illuminant C are only available at Munsell values 1/, 2/, 3/, 4/, 5/, 6/, 7/, 8/, and 9/. It is therefore necessary to substitute Y at a specific Munsell value into the preceding equations in order to solve for X and Z. Values are taken from loci charts of constant hue and chroma at the specific Munsell value under consideration at any particular point where the constant hue and chroma loci intersect. The x and y values obtained are then substituted into the equations. Since $x + y + z = 1$, the value for z is readily found and can also be substituted therein. Thus, two equations with two unknowns can be solved for X and Z. X, Y and Z values for any particular constant hue and chroma loci intersection may then be substituted into the equations given for the Hunter Color and Color-Difference Meter for converting to I. C. I. specifications of color *(2)*:

$$L = 100\ (Y^{1/2})$$

$$a_L = \frac{175\ (1.02\,X - Y)}{Y^{1/2}}$$

$$b_L = 70\ \frac{(Y - 0.847Z)}{Y^{1/2}}$$

In this manner it is possible to obtain chromaticity diagrams in terms of Hunter Color and Color-Difference Meter L, a and b readings which can be used to convert directly to the Munsell color system.

Younkin used Munsell renotations for value 3/ plotted in terms of Hunters' a_L and b_L for plotting Hunter readings obtained on various tomato purees in order to evaluate the color of puree objectively *(25)*. This method of converting Hunter a_L and b_L values to Munsell terms assumes very little difference in L readings which are related to Munsell value. So long as there is little difference between L readings, this method is quite satisfactory for obtaining Munsell hue and chroma. However, if differences are great in L readings, it becomes necessary to interpolate hue and chroma depending on the Munsell value between two of the available chromaticity diagrams *(20)*.

PROCEDURE

Conversion of Hunter L, a_L, and b_L readings to Munsell renotations. The Hunter Color and Color-Difference Meter is a photoelectric tristimulus color meter measuring color on three

[a] Journal Article No. 42-55 of the Ohio Agricultural Experiment Station, Wooster, Ohio.

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scales by using 3 filters that approximate the X, Y, and Z functions of the I. C. I. system *(2, 8)*. Three values are obtained for each color measured: R_d (45° 0° luminous reflectance) and/or L (visual lightness) depending on the type of measuring circuit selected; and "a" and "b" values which determine hue and chroma. The unit of color measurement for these 3 scales is the National Bureau of Standards (N. B. S.) unit of color difference devised by Judd *(13)*.

Judd *(14)* states that "In general, satisfactory accuracy can be expected from such photoelectric tristimulus colorimeters for the determination of small color differences between nonmetameric pairs, and even for measurements of fairly sizeable nonmetameric color differences . . . ." The standards used should not differ too drastically from the unknown in spectral selectivity.

To convert Hunter L, a_L and b_L readings to Munsell hue, value and chroma for evaluation of color changes, L readings were first substituted into Hunter's equation: $L = 100\ Y^{1/2}$ solving for Y, the equation becomes:

$$Y = (L/100)^2$$

The number obtained for Y was converted to Y_x (%) by multiplying by 100. The correct Munsell value renotation was obtained from tables given by Nickerson *(20)*.

After converting all Hunter L readings to Munsell value renotations, it was found that all color measurements of tomato juice samples taken during the study of processing methods were more than a Munsell value of 2/ and less than 4/. Since this variation occurred in Hunter L readings during processing of tomato juice, it was not feasible to obtain Munsell hue and chroma renotations from a chromaticity diagram for Munsell value 3/. In many cases this would have given hue and chroma erroneously. Thus chromaticity diagrams in terms of Hunter's a_L and b_L were constructed from Younkin's data *(24)* for Munsell values of 2/, 3/, and 4/ (Figures 1, 2 and 3) to obtain Munsell hue and chroma renotations corrected for value.

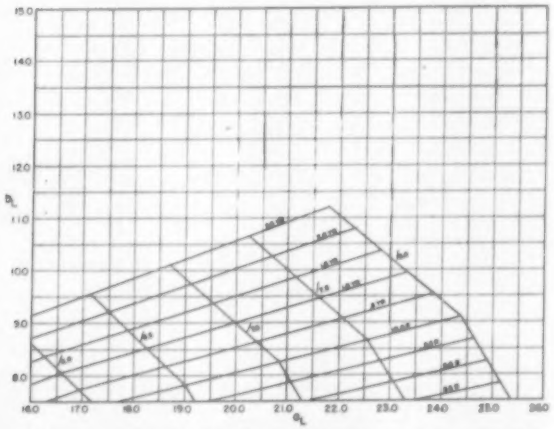

Figure 1. Chromaticity diagram at value 2/ to convert Hunter a_L and b_L to Munsell hue and chroma.

To estimate hue and chroma renotations of any point which falls within the boundaries of an area established by two hue loci and two chroma loci: e.g., 7.5R to 10.0R and /6 and /8 chroma, each of these areas included in Figures 1, 2 and 3 were further divided geometrically into .5 hue units and .5 chroma units to facilitate conversion to Munsell terms. Each color measurement reading from the Hunter Color and Color-Difference Meter for each sample was corrected for Munsell value in the following manner:

The L reading was converted to Munsell value. Munsell value was then used to determine which two of the three chromaticity diagrams at values 2/, 3/, or 4/ to use in order to obtain hue and chroma renotations from Hunter a_L and b_L readings.

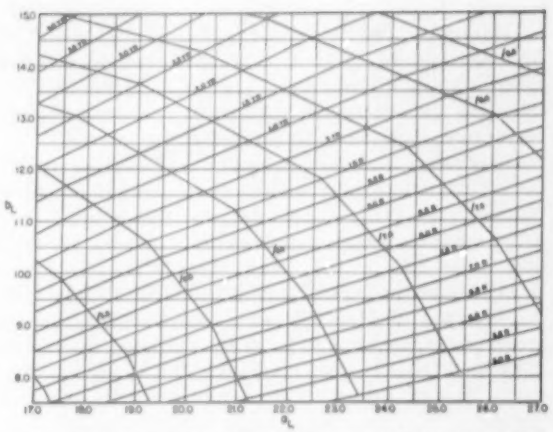

Figure 2. Chromaticity diagram at value 3/ to convert Hunter a_L and b_L to Munsell hue and chroma.

After determining hue and chroma renotations from the two appropriate chromaticity diagrams, the corrected hue and chroma were obtained by arithmetical interpolation after the method of Nickerson *(20)*, between the hue and chroma values from the two chromaticity diagrams depending upon the determined Munsell value of the sample.

For example, an L reading of 22.7 when converted to Munsell value gives 2.65. Assume also an a_L reading of +22.0 and a b_L reading of +10.0.

Then, from the chromaticity diagrams at Munsell value of 2/ and 3/:

At value 2.00/	hue = 1.4 YR*	chroma = /7.7
At value 3.00/	hue = 8.2 R	chroma = /6.5
Difference	hue = 3.2	chroma = 1.2
.65 times difference	hue = 2.08	chroma = .78
Corrected to value 2.65 (by subtracting from 2.00/)	hue = 9.3 R	chroma = /6.9

*For the purpose of interpolation, a hue of 1.4 YR was considered to be 11.4 R, thus facilitating calculations.

DISCUSSION

While attempting in this study to relate the Munsell hue, value, and chroma renotations obtained by converting Hunter readings to the Munsell color system, certain discrepancies became apparent with the work reported by MacGillivray in 1931 *(17)*. When attempting

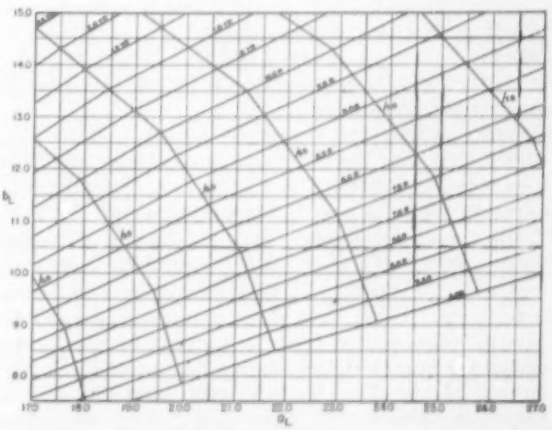

Figure 3. Chromaticity diagram at value 4/ to convert Hunter a and b to Munsell hue and chroma.

to relate Munsell color renotations calculated from Hunter readings to calculated hue, value, and chroma of the Maxwell spinning disks used in color grading of canned tomato juice, discrepancies were also apparent. The following data were taken to point out these discrepancies and, if possible, to determine the reasons.

In relating Munsell hue, value and chroma renotations obtained in these studies to the work reported by MacGillivray *(17)*, it was observed that Munsell hues as reported for tomato colors were, in general, considerably lower (5R to 9R) than Munsell hues calculated from Hunter readings (7R to 12R and/or 2YR). Munsell chromas of MacGillivray's report were in general considerably higher (/8 to /13) compared to chromas calculated from Hunter readings (/5.5 to /8.0). However, Munsell values were in approximately the same range.

For the most part, it is believed these differences may be explained by the fact that in MacGillivray's studies, the data were collected and interpreted in terms of the Munsell nominal notations. These nominal notations refer to the early color notations of color chips expressed in units of visual differences of the three psychological attributes of color: hue, value and chroma *(20)*. However, a "study of the spacing of the Munsell system was made by a subcommittee of the Colorimetry Committee of the Optical Society of America. Reports of this committee presented charts and tables constituting the definition of a psychophysical system smoothed on I. C. I. diagrams in relation to colorimetric measurements provided for the Munsel chips" *(20)*. This smoothed Munsell system is now used as the basis for exact color measurement work, the colors of the Munsell color chips being expressed in terms of the "renotation" provided by the smoothed system and the psychological color solid thereby defined. The smoothed system is now used when accurate instead of approximate data are needed *(20)*.

Thus, for example, the nominal notation of the red disk used in the spinner for grading tomato juice color *(1)* of 5R 2.6/13 had an actual notation ("re-notation") of 6.7R 3.07/9.2. This explains in part the lower Munsell hues and higher Munsell chromas of MacGillivray's studies on tomato colors *(17)*.

However, since MacGillivray's studies were not concerned with color changes during the processing of tomato juice, it was believed that little would be gained by attempting to convert his data to the smoothed system for comparison purposes.

Along similar lines of thought, Gould *et al. (8)* have shown that the instrumental illuminating conditions used with the Hunter Color Difference Meter have an effect on the L, a_L and b_L readings obtained. In Table 1, the averages calculated from readings of 20 tomato puree samples *(8)* are given. In addition, these readings were converted to Munsell hue, value, and chroma renotations. These data show that conversion to the Munsell color system would be affected by illuminating conditions used with the Hunter Color and Color Difference Meter. The data also show that the two extremes in Munsell hue, value, and chroma renotations were obtained with illumination conditions 1 (small area illumination with small aperture) and 4 (large area illumination with large aperture).

Since the illumination conditions used with the Hunter instrument in a study of the effect of processing methods on tomato juice color were small area of illumination and small aperture, illumination conditions were studied to determine the extent of these discrepancies.

TABLE 1

Munsell hue, value and chroma renotations calculated from the data of Gould et al. (8) for Averages Calculated from readings of twenty tomato puree samples using different instrumental illuminating conditions with the Hunter Color Difference Meter.

Illumination conditions*	Average	Hunter Readings		Munsell Renotations		
	L	a_L	b_L	Hue	Value	Chroma
1	25.5	22.7	12.8	.80YR	2.99	7.4
2	26.5	25.2	13.3	.48YR	3.10	8.0
3	25.7	23.3	12.4	.30YR	3.01	7.3
4	27.3	26.8	13.1	9.9R	3.20	8.2

*1—Small area illumination with small aperture.
2—Small area illumination with large aperture.
3—Large area illumination with small aperture.
4—Large area illumination with large aperture.

The Munsell hue, value, and croma renotations were calculated from I. C. I. values provided for each color disk in the spinning disk by the Munsell Color Company. Also, the disks were measured by means of the Hunter Color Difference Meter while spinning above the viewing aperture and the Hunter readings were converted to Munsell hue, value, and chroma renotations.

Munsell hue, value, and chroma renotations calculated from I. C. I. values for Illuminant "C" (specular exponent excluded) and from Hunter Color Difference Meter readings taken when spinning the disks above the viewing aperture using the two extremes of area of illumination and size of aperture are given in Table 2. These data show little difference between the two extremes of illumination conditions when measuring the color of the spinning disks by the Hunter meter and then converting readings to the Munsell color system. However, Munsell hue, value, and chroma renotations calculated from I. C. I. values for Illuminant "C" (specular exponent excluded) show slight discrepancies with data calculated from the Hunter readings.

From the data given in Tables 1 and 2 there are certain inferences that may be drawn to explain these variations. The first is that measuring the actual spinning disks under different instrumental illumination conditions of the Hunter Color Difference Meter gives essentially the same results. Secondly, Munsell hue, value, and chroma renotations from Hunter readings do not agree exactly with those calculated from I. C. I. data available for the spinning disks.

These data indicate that when Hunter readings are converted to Munsell hue, value, and chroma renotations they may not always agree perfectly with Munsell hue, value, and chroma renotations of spinning disks.

In addition, the discrepancies pointed out in Table 1 between Munsell hue, value, and chroma renotations for different instrumental illumination conditions are not fully explained when measuring the color of samples of tomato puree. However, depending upon the

TABLE 2

Agreement between calculations of Munsell hue, value, and chroma renotations from I.C.I. values for nominal notations of papers used in Maxwell spinning disks and from Hunter color difference meter data taken by determining the color of spinning disks of varying percentages of papers of nominal notations used for determining the color score of canned tomato juice

Percent[1]	Nominal notations	Calculated from I. C. I. values for illuminant "C" (specular exponent excluded)[2]		Calculated from Hunter color difference meter data by spinning disk above aperture			
				Large aperture using large area illumination		Small aperture using small area illumination	
		Hue	Value/Chroma	Hue	Value/Chroma	Hue	Value/Chroma
65 21 14 0	5R 2.6/13 2.5YR 5/12 N1 (glossy) N4 (mat)	9.6R	3.59 8.3	9.89R	3.30 9.0	9.89R	3.32 9.8
65 21 7 7	5R 2.6/13 2.5YR N1 (glossy) N4 (mat)	9.2R	3.72 8.1	9.77R	3.54 8.9	9.88R	3.51 9.4
65 21 0 14	5R 2.6/13 2.5YR 5/12 N1 (glossy) N4 (mat)	9.0R	3.85 7.7	9.74R	3.68 8.4	9.72R	3.64 8.7
53 28 9 0	5R 2.6/13 2.5R 5/12 N1 (glossy) N4 (mat)	.47YR	3.74 8.3	.56YR	3.47 8.5	.51YR	3.54 9.4
53 28 9.5 9.5	5R 2.6/13 2.5YR N1 (glossy) N4 (mat)	1.62YR	3.91 8.5	.49YR	3.74 8.3	.36YR	3.72 8.9
53 28 9.5 19	5R 2.6/13 2.5YR 5/12 N1 (glossy) N4 (mat)	9.6R	4.06 7.2	.04YR	3.88 8.2	.24YR	3.88 8.3

[1] U. S. Standards for Grades of Tomato Juice (Canned or Bottled) state that with the minimum grade A disk and with the minimum Grade C disk any combination of black (N1-glossy) or gray (N4-mat) may be used in order to match the color of the sample. Spinning disks measured represent the extremes as well as half black for the two minimums.

[2] I. C. I. values received in personal communication from Munsell Color Company, Baltimore, Maryland.

manner of illumination, it seems possible that the amount of reflected light and/or the spectral characteristics of this reflected light may vary more with a semi-opaque liquid sample (such as tomato puree or tomato juice) than with solid materials (such as the spinning disk). Large area illumination spreads the light from the light source over the entire aperture in a relatively diffuse manner; whereas, small area illumination concentrates the light in a small spot within the aperture. Therefore, it would seem that with small area illumination (concentrated light beam) there would be more possibility of light loss or lateral dispersion of light. There may be other valid explanations; however, these are thought to be logical deductions.

Although these discrepancies exist, when comparing manufacturing processes for tomato juice, it is believed that conversion of Hunter data taken with small area illumination and small aperture to Munsell hue, value, and chroma renotations by the procedure outlined in this paper may logically be used to determine the nature of these changes.

SUMMARY

A method is proposed for converting Hunter Color Difference Meter readings of tomato juice samples to Munsell hue, value, and chroma renotations which are corrected for Munsell value renotations. The proposed method increases the accuracy of interpretations of color data obtained by converting Hunter L, a_L and b_L readings to Munsell hue, value, and chroma renotations.

Different instrumental illuminating conditions used with the Hunter Color Difference Meter for measuring colors of tomato products were shown to have a marked effect on Munsell hue, value, and chroma renotations calculated from the Hunter readings. Hunter readings of tomato puree taken with small area illumination and small aperture when converted to Munsell hue, value, and chroma renotations were found to have higher Munsell hue renotations, lower Munsell value renotations and lower Munsell chroma renotations than converted readings taken with large area illumination and large aperture.

However, when the colors of Munsell spinning disks were measured by the Hunter meter using different instrumental illumination conditions, essentially the same results were obtained when readings were converted to Munsell hue, value, and chroma renotations. Therefore, the illumination conditions used influence light loss and/or lateral light loss from semi-opaque liquid samples such as tomato puree or tomato juice which affect the amount of reflected light and/ or the spectral characteristics of light reflected from the samples during measurement.

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The Effect of Processing Methods on the Color of Tomato Juice[a,b]

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The color of canned tomato juice is studied in relation to four methods of processing. It is demonstrated that hue, value, and chroma must be taken into consideration when attempting to relate objective color measurements in Munsell terms to visual color evaluation.

This study was conducted to determine the effect of the following processing methods for the manufacture of canned tomato juice on the color of the canned product: (a) "hot-break," high-temperature, short-time process; (b) "cold-break," high-temperature, short-time process; (c) "hot-break," conventional retort process; and (d) "cold-break," conventional retort process.

According to Blumer *et al. (2)*, "The method of high-temperature, short-time flash presterilization involves rapid heating of juice to temperature high enough to destroy *B. thermoacidurans* followed by rapidly cooling to about 200° F., filling into cans, closing, inverting and holding for one to three minutes, and then water cooling. This method has become widely accepted and in the last five years, a large number of canners have installed equipment for the presterilization of tomato juice. . . . However, the advent of flash presterilization has introduced the problem of its effect on the color of juice."

Specific varieties and maturities of tomatoes have been shown to affect the color relationship of the raw product to the finished product in the manufacture of tomato juice *(9, 11, 16)*.

Processing methods have been investigated with respect to their effect on the color of canned tomato juice. The findings have been in general as follows: removal of certain types of defects improved the color of tomato juice *(18)*; preheeating temperatures within the range of 140° to 200° F. were not found to affect the color of tomato juice when color differences were evaluated by using the a/b color ratio as a color index *(18)*; the vibrating screen was generally found to be deleterious

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to color when using the a/b color ratio as a color index *(18)*; under "hot-break" extraction conditions, essentially no difference was found in the color of flash sterilized or conventionally retort processed tomato juice *(2)*; and increasing pasteurization temperatures were found to produce poorer colored tomato juice by using the a/b color ratio as a color index, although equivalent F_o values were not used *(18)*.

Additionally, only a limited amount of information was available in the literature on the effect of storage on tomato juice color. No data were found concerning the effect of temperature of storage on the color of canned tomato juice. Although Blumer *et al. (2)* have shown that the color of standard (Grade C) tomato juice improves during storage when evaluated visually, Judd's color index *(13)* for objective color evaluation did not show this improvement. However, the methods by which the tomato juice color were evaluated visually were not given in detail, and it has been previously pointed out *(7, 8)* that conditions for visual evaluation of color must be carefully controlled to obtain comparable results.

Several workers have drawn conclusions regarding the effect of processing methods and storage on the color of tomato juice *(2, 16)*. The most widely used color index for evaluating color changes in tomato products during processing has been the Hunter a/b color ratio *(3, 5, 6, 9, 10, 11, 12, 14, 15, 17, 18, 19)*. In addition, Judd's color index *(13)* has been used for color evaluation of both processing methods and changes during storage of canned tomato juice. It should be pointed out that it is impossible to convert these indices to a standard color system in many cases. Therefore, at the present time, before considerably more data is collected concerning the effect of processing variables and storage, it would seem desirable to adopt a standardized method of presenting color data.

In this study, the color of samples of tomato juice was measured by means of the Hunter Color and Color-Difference Meter. All Hunter L, a_L and b_L readings were interpreted in terms of Munsell hue, value, and chroma renotations with Munsell hue and chroma renotations corrected for Munsell value as previously reported *(4)*. Color scores of the canned product were determined by official inspectors of the U. S. Department of Agriculture by comparing the color of samples of tomato juice to the color of specified Munsell spinning disks *(1)*.

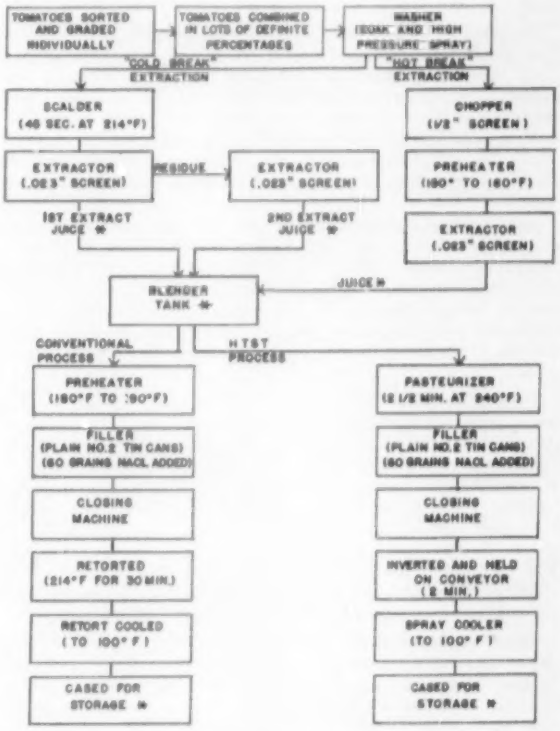
PROCEDURES

Processing procedures. The Rutgers variety of tomatoes, grown in 1951 on the Horticultural Farm at the Ohio State University was used *(9)*. Harvesting was started when the fruits were mature enough to comply with the quality desired for processing in the pilot plant and continued at weekly intervals throughout the season.

The tomatoes were graded by an official inspector of the Federal-State Fruit and Vegetable Inspection Service. Each tomato was graded and segregated according to the factors of color as outlined in the U. S. Standards for Manufacture of Strained Tomato Products *(9)*. Graded and sorted tomatoes were then recombined in 500-pound lots of definite percentages before processing to give lots of varying maturities of raw product and of varying quantities for these studies.

As shown in Figure 1, the lots of tomatoes for juice manufacture were placed in an air-agitated soaker washer for 3 to 5 minutes and conveyed on a roller-type washer which elevated the tomatoes under a 120-130 pounds high-pressure water spray.

For the "cold-break" two extraction process, the tomatoes were conveyed directly from the washer, scalded in live steam for 45 seconds, and conveyed to a Langsenkamp Model B extractor with a screen having .023 inch openings for extraction. The residue from the first extraction was again extracted (2nd extract). Juice from the 2 extractions was combined in a blending tank for further processing (Figure 1).


TOMATOES SORTED AND GRADED INDIVIDUALLY
TOMATOES COMBINED IN LOTS OF DEFINITE PERCENTAGES
WASHER (SOAK AND HIGH PRESSURE SPRAY)
"COLD BREAK" EXTRACTION
"HOT BREAK" EXTRACTION
SCALDER (45 SEC. AT 214°F)
CHOPPER (1/2" SCREEN)
EXTRACTOR (.023" SCREEN)
RESIDUE
EXTRACTOR (.023" SCREEN)
PREHEATER (180° TO 190°F)
1ST EXTRACT JUICE
2ND EXTRACT JUICE
EXTRACTOR (.023" SCREEN)
JUICE
BLENDER TANK
CONVENTIONAL PROCESS
HTST PROCESS
PREHEATER (180°F TO 190°F)
PASTEURIZER (2 1/2 MIN. AT 240°F)
FILLER (PLAIN NO.2 TIN CANS) (60 GRAINS NACL ADDED)
FILLER (PLAIN NO.2 TIN CANS) (60 GRAINS NACL ADDED)
CLOSING MACHINE
CLOSING MACHINE
RETORTED (214°F FOR 30 MIN.)
INVERTED AND HELD ON CONVEYOR (2 MIN.)
RETORT COOLED (TO 100° F.)
SPRAY COOLER (TO 100° F.)
CASED FOR STORAGE
CASED FOR STORAGE

* INDICATES SAMPLING POINTS FOR COLOR MEASUREMENT.

Figure 1. Flow sheet of procedures for manufacture of tomato juice in OSU pilot plant.

For the "hot-break" process, the washed tomatoes were conveyed to a Fitzpatrick Model D Comminuting Machine (No. 6 screen with ¼-inch openings) for chopping. The chopped tomatoes were then pumped through a tube preheater, heated to a temperature of approximately 180° F. and pumped to the Model B extractor for juice extraction, after which the extracted juice was pumped to the blending tank (Figure 1).

Extracted juice from 500-pound lots of tomatoes was divided with part of the juice processed by the HTST process (high temperature, short time) and part by the conventional retort process. Thus, it was possible to study the effect of processing methods on the color of tomato juice manufactured from identical raw stock when using either the "hot-break" or the "cold-break" extraction methods.

Following the "hot-" or "cold-break" methods of extraction, one-half of the extracted and blended juice was pumped to a Walker-Wallace Paraflow Plate Heat Exchanger. Here the juice was heated to 240° F. and held 2½ minutes before cooling to approximately 205° F. (the HTST process) and then filled into No. 2 plain tin cans with a 60-grain sodium chloride tablet added. The filled cans were sealed, inverted, held 2½ to 3 minutes, and spray cooled to approximately 100° F. before casing for storage.

In addition, the remaining half of the extracted juice from the "cold-break" or "hot-break" methods of extraction was preheated with a continuous tube preheater to 180° F., filled directly into No. 2 plain tin cans with a 60-grain sodium chloride salt tablet added. The cans of tomato juice were then sealed, inverted, placed in a retort crate (150 No. 2 capacity) and processed at 1 to 2 pounds steam pressure (214° to 216° F.) for 30 minutes (the conventional retort process). Process time and temperature were automatically controlled and recorded. After processing, the cans of tomato juice were cooled in the retort with cold water to approximately 100° F. before casing for storage. The canned tomato juice was held at room temperature until color measurements were made.

Preparation of samples for color measurement. *Raw Sample.* For the "cold-break" extraction method, samples of tomato juice for the evaluation of color changes were taken at the extractor (first and second extraction of juice and also from the blend of the two extracts). For the "hot-break" extraction method, samples for color evaluation were taken at the chopper (juice for color measurement was obtained by extracting the chopper sample in a Cefaly pulper), at the extractor, and at the filler.

Due to the incorporation of air into the pureed sample, deaeration was necessary to remove the air which could have caused erroneous readings *(9)*. All samples were deaerated except the "hot-break" samples taken at the extractor and filler and the canned samples. It was found that deaeration of hot or canned juice was unnecessary. After deaeration of the juice sample, it was poured into a viewing cell *(9)* for color measurement.

Canned sample. After 1, 5, and 10 months' storage, a composite sample for color measurement was taken from each 6 cans of each lot. Each lot was also graded for color in accordance with U. S. Standards for Grades of Tomato Juice *(1)* by two official inspectors from the U. S. Department of Agriculture. Color scores were assigned by comparing the sample of canned tomato juice to Munsell spinning disks as specified in the U. S. Standards for grades of tomato juice *(1)*. Since all lots were uniform with respect to the U. S. Department of Agriculture color score assigned for each of the 6 cans graded, the composite samples represented one individual color score.

Color measurements. A Hunter Color and Color-Difference Meter was used to measure the color of both the raw and canned tomato juice. The meter was standardized before taking readings on the L, a_L and b_L scales by using a tomato red porcelain tile[6] with a setting as follows: L, 25.59; $a_L + 27.40$; $b_L + 12.54$. In all color measurements, the conditions of illumination and exposure of the sample within the Hunter Meter were small area of illumination and small aperture (1⅛ inches in diam.). All Hunter L, a and b readings obtained were converted to Munsell hue, value, and chroma as previously described *(4)*.

DISCUSSION

"Cold-break" HTST process vs. conventional process. Munsell hue renotations of samples for the "cold-break" HTST and conventional retort processes are presented in Table 1. There was no significant difference between means of the samples taken of the juice at the first extraction and the blender, although the Munsell hue renotation mean of the samples of the second extract was significantly lower (more red) than that of the first extract. However, the effect on the color of the blended juice with respect to hue was neither detrimental nor beneficial. In addition, no significant differences in Munsell hue renotation means were found between 1, 5, and 10 months' storage.

Table 1 gives data for comparing the "cold-break" conventional process with the HTST process. After extraction and blending of the tomatoes composing each of the above lots, the juice obtained was divided into two equal portions, one-half of which was processed by each of the processes mentioned.

Comparing hue renotation means of the stages in manufacture and storage by the L. S. D. for processes and lots (0.42), the hue renotation means for tomato juice produced by the conventional retort process had

TABLE 1

Munsell Hue renotations calculated from Hunter Color Difference Meter readings of tomato juice samples for the "cold-break" HTST process compared to the "cold-break" conventional retort process taken at the extractor (1st and 2nd extracts), blender and after 1, 5, and 10 months' storage

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Extractor						
		(1st)	(2nd)	Blender	1	5	10	
1	CB-C	8.5	7.9	8.5	10.3	10.6	9.8	9.27
	CB-HTST	8.5	7.9	8.6	9.2	9.1	8.9	8.70
2	CB-C	9.2	8.7	8.4	11.2	11.2	11.3	10.00
	CB-HTST	9.6	8.7	8.5	9.8	10.0	10.6	9.53
3	CB-C	9.8	8.9	9.8	11.7	11.2	11.1	10.42
	CB-HTST	9.0	9.1	8.9	10.5	10.1	10.1	9.62
4	CB-C	8.9	8.2	8.5	10.5	10.6	10.3	9.50
	CB-HTST	8.1	7.9	8.5	10.0	10.1	10.2	9.13
Average	CB-C	9.10	8.43	8.80	10.93	10.90	10.63	
Average	CB-HTST	8.80	8.40	8.63	9.87	9.83	9.95	
Mean		8.95	8.41	8.71	10.40	10.36	10.29	

L. S. D. for stages in manufacture and storage.....at .01 level = .38
L. S. D. for processes and lots.....at .01 level = .42

[1] CB-C—Cold-break Conventional Retort Process.
CB-HTST—Cold-break High-Temperature-Short-Time Process.

significantly higher hue renotations (more toward yellow red) in 3 of the 4 lots processed. The hue renotation mean of tomato juice of the fourth of these 4 lots for the conventional process was not significantly higher. These data indicated that with respect to Munsell hue renotations, the "cold-break" conventional process produced tomato juice of a slightly inferior color.

The higher Munsell hue renotations produced in tomato juice manufactured by the conventional retort process are also indicated by comparing the averages of the 4 lots processed to averages of the 4 comparable lots processed using the HTST process (Table 1, Figure 2). Additionally, these data show that for both of these processes, Munsell hue renotations of tomato juice are increased during processing.

USDA color scores for tomato juice from the above two processes (Table 2) show that although hue renotation means for tomato juice of the HTST process

TABLE 2

USDA color scores of tomato juice produced by the "cold-break" HTST and conventional processes

Lot no.	USDA color scores (Averages of 1, 5, and 10 months' storage	
	HTST	Conventional
1	29.3	29.3
2	27.6	27.3
3	27.3	28.0
4	28.0	27.3
Grand average	28.1	28.0

[6] Furnished by Dr. S. G. Younkin, Campbell Soup Co.

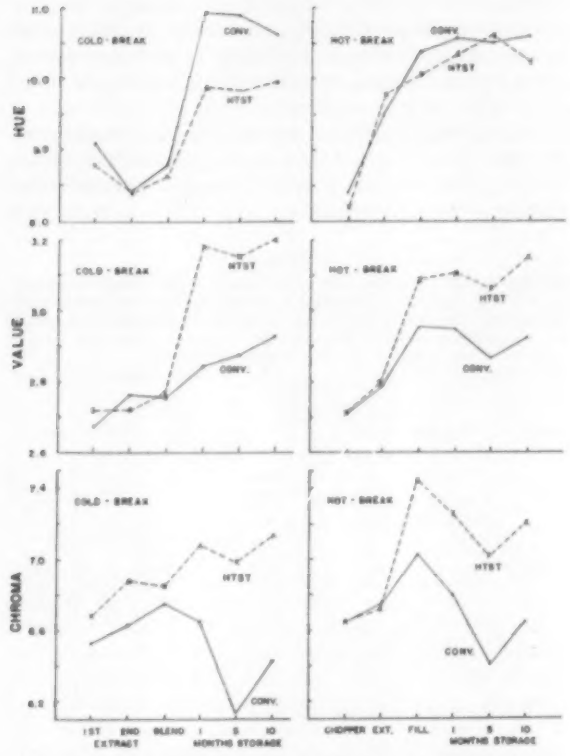


Figure 2. Comparison of Munsell hue, value and chroma renotations of tomato juice produced by the "cold-break" and "hot-break" HTST and conventional retort processes and changes occurring during stages in manufacture and storage.

were generally lower (more red) than for the conventional process, the grand averages of USDA color scores for 1, 5, and 10 months' storage indicated little difference in color scores for canned tomato juice manufactured either by the "cold-break" HTST process or the conventional process.

Table 3 gives Munsell value renotations of samples of tomato juice from the "cold-break" HTST and conventional retort processes. The L. S. D. of .089 between stages in manufacture and storage showed no significant differences between Munsell value renotation means of samples of tomato juice from the first extract, second extract, and blender. Munsell value renotation means of tomato juice after 1, 5, and 10 months' storage were in all cases significantly higher (lighter grayness) than means of the extractor and blender samples. But there were no significant differences in Munsell value renotation means of tomato juice due to storage.

With respect to the effect of the "cold-break" HTST and conventional process on Munsell value renotations of tomato juice, in all cases the means of stages in manufacture and storage of Munsell value renotations of tomato juice from the conventional process were significantly lower than for tomato juice from the HTST process. The lower Munsell value renotations of tomato juice from the conventional retort process are also shown by comparing the averages to those of tomato juice from the HTST process (Table 3, Figure 2). Thus, these data would indicate a darker shade of the particular red or yellow red hue in the finished product and may possibly explain why greater differences were not found in USDA color score averages of tomato juice between the two processes above (Table 2). The darker shade possibly nullifies the higher Munsell hue renotations (more yellow red) of tomato juice obtained from the conventional process.

TABLE 3

Munsel Value Renotations calculated from Hunter Color Difference meter readings of tomato juice samples for the "cold-break" HTST process compared to the "cold-break" conventional retort process taken at the extractor (1st and 2nd extract), blender and after 1, 5, and 10 months' storage

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Extractor						
		(1st)	(2nd)	Blender	1	5	10	
1	CB-C	2.68	2.68	2.69	2.88	2.77	2.89	2.765
	CB-HTST	2.68	2.68	2.69	3.11	3.07	3.19	2.903
2	CB-C	2.77	2.83	2.85	2.91	2.91	2.96	2.872
	CB-HTST	2.77	2.83	2.88	3.38	3.28	3.26	3.067
3	CB-C	2.44	2.71	2.71	2.58	2.83	2.87	2.690
	CB-HTST	2.62	2.53	2.74	2.95	3.01	3.05	2.817
4	CB-C	2.80	2.82	2.77	3.01	2.99	2.99	2.897
	CB-HTST	2.80	2.82	2.77	3.29	3.24	3.30	3.037
Average	CB-C	2.673	2.760	2.755	2.845	2.875	2.928	
Average	CB-HTST	2.718	2.715	2.770	3.183	3.150	3.200	
Mean		2.695	2.738	2.763	3.014	3.013	3.064	

L. S. D. for stages in manufacture and storage.....at .01 level = .089
L. S. D. for processes and lots.....at .01 level = .096

[1] CB-C—Cold-break Conventional Retort Process.
CB-HTST—Cold-break High-Temperature-Short-Time Process.

Table 4 gives data for Munsell chroma renotations of samples of tomato juice produced by the "cold-break" HTST and the conventional retort processes.

Munsell chroma renotation means of tomato juice from two of the 4 lots of tomatoes processed were significantly higher (brighter color) for the HTST process. In addition, chroma renotation means of tomato juice from the HTST process also were higher for the other 2 lots even though not significantly higher.

TABLE 4

Munsell Chroma Renotations calculated from Hunter Color Difference meter readings of tomato juice samples for the "cold-break" HTST process compared to the "cold-break" conventional retort process taken at the extractor (1st and 2nd extract), blender and after 1, 5, and 10 months' storage

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Extractor						
		(1st)	(2nd)	Blender	1	5	10	
1	CB-C	6.7	7.1	6.8	6.7	6.2	6.6	6.68
	CB-HTST	6.7	7.0	6.8	7.6	7.1	7.4	7.10
2	CB-C	6.1	6.1	7.0	6.2	5.5	5.7	6.10
	CB-HTST	7.3	6.9	7.0	6.2	7.2	6.4	6.83
3	CB-C	6.9	6.5	6.6	6.8	6.0	6.5	6.55
	CB-HTST	6.3	6.8	7.0	7.2	6.7	7.0	6.83
4	CB-C	6.4	6.8	6.6	6.9	6.8	6.9	6.73
	CB-HTST	6.4	6.8	6.6	7.3	6.9	7.7	6.95
Average	CB-C	6.53	6.63	6.75	6.65	6.13	6.43	
Average	CB-HTST	6.68	6.88	6.85	7.08	6.98	7.13	
Mean		6.60	6.75	6.80	6.86	6.55	6.78	

L. S. D. for processes and lots at .01 level = .39

[1] CB-C—Cold-break Conventional Retort Process.
CB-HTST—Cold-break High-Temperature-Short-Time Process.

The average of Munsell chroma renotations of tomato juice from the cold-break conventional retort and HTST processes (Table 4 and Figure 2) also indicate higher chroma renotations (brighter color) of tomato juice produced by the HTST process.

It should also be noted that chroma renotations of the canned tomato juice decreased after 5 months' storage and then again increased after 10 months' storage. This decrease, however, did not affect the visual color evaluation since little difference is shown in average color scores assigned by USDA inspectors after 1, 5, and 10 months' storage (Table 5).

Thus, data in Table 4 and Figure 2 indicate that Munsell chroma renotations of tomato juice were higher (brighter color) for the "cold-break" HTST process than for the "cold-break" conventional retort process.

In comparing the "cold-break" HTST and conventional retort processes in terms of Munsell hue, value, and chroma renotations, and USDA color scores, little difference was found between the two processes with regard to the average USDA color scores of canned tomato juice. This agrees generally with the results of Blumer *et al. (2)*, who showed that high-temperature-short-time flash presterilization of tomato juice did not produce tomato juice of inferior color to that produced by conventional processes, and that with either process, color did not improve during storage using the color index previously explained. However, Blumer *et al. (2)* stated that these results did not agree with their visual color evaluations. Table 5 presents data for the average USDA color scores of tomato juice from all lots for the two processes after 1, 5, and 10 months' storage.

TABLE 5

USDA average color scores of tomato juice produced by the "cold-break" HTST and conventional retort processes after 1, 5, and 10 months' storage

Process	USDA color score after storage		
	1 month	5 months	10 months
CB-C	27.8	28.3	28.0
CB-HTST	28.3	28.0	29.0

Data presented in Table 5 show, contrary to the work of Blumer *et al. (2)* in the case of the effect of storage on visual color evaluations, that USDA color scores of tomato juice were not appreciably different either due to process or storage. This agrees with Munsell hue, value, and chroma renotation data presented in Tables 1, 3, and 4; namely, that there were no significant differences between Munsell hue, value, or chroma renotation means of canned tomato juice after 1, 5, and 10 months' storage.

Munsell hue renotations were not the main factor in determining visual color scores of tomato juice when comparing these processes. For example, although Munsell hue renotation means of tomato juice from the "cold-break" HTST process were significantly lower (more red) in 75% of the comparison lots processed, visual color scores assigned the finished product did not appreciably differ. It is believed that significantly lower Munsell value renotation means of tomato juice from lots of the "cold-break" conventional process were responsible for nullifying the differences found in Munsell hue and chroma renotations. Furthermore, these data indicate that lowering the Munsell value renotation of tomato juice would have a desirable effect on the color score of the canned product.

"Hot-break" HTST process vs. conventional process. Table 6 gives Munsell hue renotations of samples for the "hot-break" HTST pasteurized and conventional retort processes.

TABLE 6

Munsell Hue Renotations calculated from Hunter Color ence Meter readings of tomato juice samples for the "hot-break" HTST process compared to the "hot-break" conventional retort process taken at the chopper, extractor, filler and after 1, 5, and 10 months' storage

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Chopper	Extractor	Filler	1	5	10	
1	HB-C	7.9	9.0	9.9	10.3	10.2	9.9	9.53
	HB-HTST	7.6	9.2	9.9	10.1	10.2	10.0	9.50
2	HB-C	8.5	9.6	10.5	10.8	10.7	10.8	10.15
	HB-HTST	8.0	9.9	10.0	10.4	10.9	10.4	9.93
3	HB-C	8.6	9.6	10.6	10.7	10.8	11.0	10.22
	HB-HTST	8.6	9.9	10.0	10.3	10.8	10.1	9.95
4	HB-C	8.7	10.0	10.5	10.5	10.4	10.7	10.13
	HB-HTST	8.6	10.1	10.4	10.5	10.5	10.4	10.08
Average	HB-C	8.42	9.55	10.38	10.58	10.53	10.60	
Average	HB-HTST	8.20	9.78	10.08	10.33	10.60	10.23	
Mean		8.31	9.66	10.23	10.45	10.56	10.41	

L. S. D. for stages in manufacture and storage ..... at .01 level = .21
L. S. D. for processes and lots ..... at .01 level = .23

[1] HB-C—Hot-break Conventional Process.
HB-HTST—Hot-break High-Temperature-Short-Time Process.

When comparing means for stages in manufacture and storage, the data in Table 6 show that the mean of Munsell hue renotations for the samples of tomato juice taken at the extractor was significantly higher than for the mean of samples taken at the chopper; also, the mean of the hue renotations of the samples taken at the filler was significantly higher than for the mean of samples taken at the extractor. Means of hue renotations of samples of tomato juice after 1 and 5 months' storage were significantly higher than the mean of samples taken at the filler. But there was no significant difference after 10 months' storage. Again, there were no significant differences between hue renotation means of samples of tomato juice after 1, 5, and 10 months' storage.

Data were given in Table 6 to compare the effect of the foregoing processes on the color of tomato juice produced by the "hot-break" process. In all cases, hue renotation means of stages in manufacture and storage were higher (toward yellow red) for the conventional retort process than for the HTST process. However, in only one of the four comparison lots, which were divided at the blender, was the hue renotation mean of tomato juice significantly higher (toward yellow red). These data would indicate a slightly lower Munsell hue renotation of tomato juice produced by the "hot-break" HTST process compared to tomato juice from the "hot-break" conventional retort process.

When the averages of Munsell hue renotations of tomato juice from the "hot-break" conventional retort

process were compared to the averages of the "hot-break" HTST process, a slightly lower Munsell hue renotation (toward red) was obtained for the tomato juice from the HTST process, except after 5 months' storage (Table 6, and Figure 2).

Average USDA color scores of tomato juice after 1, 5, and 10 months' storage for the "hot-break" HTST and conventional processes are given in Table 7. These data show that although hue renotation means for the juice from the HTST process were slightly lower (toward red) than for the tomato juice from the conventional process, the grand averages of USDA color scores for 1, 5, and 10 months' storage indicated little difference in color scores for canned tomato juice manufactured either by the "hot-break" HTST or conventional processes.

TABLE 7

Average USDA color scores of tomato juice produced by the "hot-break" HTST and conventional processes

Lot no.	USDA color scores (Averages of 1, 5 and 10 months' storage)	
	Plate-pasteurized	Conventional
1	28.7	28.7
2	27.7	28.3
3	28.3	27.3
4	27.3	28.3
Grand Average	28.0	28.2

Munsell value renotations of samples of tomato juice for the "hot-break" HTST and conventional retort processes are given in Table 8. With regard to stages in manufacture and storage, there was no significant difference between Munsell value renotation means of the chopper and extractor samples of tomato juice. The Munsell value renotation mean of samples of tomato juice taken at the filler was significantly higher than means of samples taken at the chopper and extractor. There was no significant difference between means of samples of tomato juice taken at the filler, and after 1, 5 and 10 months' storage.

TABLE 8

Munsell Value Renotations calculated from Hunter Color Difference meter readings of tomato juice samples for the "hot-break" HTST process compared to the "hot-break" conventional retort process taken at the chopper, extractor, filler and after 1, 5, 10 months' storage.

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Chopper	Extractor	Filler	1	5	10	
1	HB-C	2.64	2.71	2.93	2.99	2.82	2.95	2.840
	HB-HTST	2.64	2.75	3.08	3.17	3.10	3.21	2.992
2	HB-C	2.78	2.88	3.00	3.04	2.89	2.94	2.922
	HB-HTST	2.78	2.93	3.15	3.15	3.16	3.22	3.065
3	HB-C	2.69	2.81	2.98	2.83	2.82	2.86	2.832
	HB-HTST	2.69	2.75	3.01	2.96	2.87	2.96	2.873
4	HB-C	2.72	2.75	2.92	2.93	2.94	2.96	2.870
	HB-HTST	2.72	2.75	3.11	3.14	3.11	3.21	3.007
Average	HB-C	2.708	2.788	2.958	2.948	2.868	2.928	
Average	HB-HTST	2.708	2.795	3.088	3.105	3.060	3.150	
Mean		2.708	2.791	3.023	3.026	2.964	3.039	

L. S. D. for stages in manufacture and storage.....at .01 level = .092
L. S. D. for processes and lots.....at .05 level = .085

[1] HB-C—Hot-break Conventional Retort Process.
HB-HTST—Hot-break High-Temperature-Short-Time Process.

With regard to the effect of these two processes on Munsell value renotations of tomato juice in the four comparison lots, Munsell value renotation means of stages in manufacture and storage were significantly higher for the "hot-break" HTST process than for the conventional retort process. Averages of the two processes also indicate higher Munsell value renotations of tomato juice from the HTST process (Figure 2).

Data presented in Table 9 are Munsell chroma renotations of samples of tomato juice for the "hot-break" HTST and conventional retort processes. Comparing means of stages in manufacture and storage, there was no significant difference between chroma renotation means of samples of tomato juice taken at the chopper and extractor. The croma renotation mean of samples of tomato juice taken at the filler was significantly higher (brighter) than the means of samples taken at the chopper, extractor, and after 1, 5, and 10 months' storage. A possible explanation for the higher chroma renotation mean of the filler samples of tomato juice may be that they were taken after the juice was pasteurized and still hot (190° F. to 200° F.). No effort was made to cool these samples immediately after taking them from the processing line. In most cases 20 minutes to an hour elapsed before reading the filler samples on the Hunter instrument. With the canned tomato juice samples, however, they were spray cooled or retort cooled immediately after holding the hot cans for 2½ minutes or retorting at 214° F. Therefore, it is believed that the higher chroma renotations of the filler samples might be attributed to this longer exposure to heat, although there was no apparent effect on Munsell hue and value renotations. The chroma renotation mean of samples of tomato juice taken after 5 months' storage was significantly lower than means of samples taken after 1 or 10 months' storage. However, there was no significant difference between chroma renotation means of samples taken after 1 and 10 months' storage. Thus, Munsell chroma renotations of canned tomato juice also decreased (decreasing brightness) in the case of the "hot-break" conventional retort process and the HTST process after 5 months' storage and then again increased after 10 months' storage. Again this decrease did not affect visual color evaluations since Table 10 shows little difference in average USDA Color Scores assigned after 1, 5, and 10 months' storage.

With respect to the effect of the foregoing two processes on chroma renotation of tomato juice, in all cases of the four comparison lots given in Table 9, Munsell chroma renotation means of stages in manufacture and storage were significantly higher (increased brightness) for the "hot-break" HTST process (Figure 2).

Comparing tomato juice produced by the "hot-break" HTST and conventional retort processes in terms of Munsell hue, value, and chroma, and USDA color scores, little difference existed between the two processes with regard to the average USDA color scores. Again, this is in general agreement with the results of Blumer *et al. (2)*.

TABLE 9

Munsell Chroma Renotations calculated from Hunter Color Difference meter readings of tomato juice samples for the "hot-break" HTST process compared to the "hot-break" conventional retort process taken at the chopper, extractor, filler and after 1, 5, and 10 months' storage

Lot no.	Process[1]	Stages of manufacture—sample points			Storage (Months)			Mean
		Chopper	Extractor	Filler	1	5	10	
1	HB-C	6.7	6.8	7.0	6.9	6.3	6.9	6.77
	HB-HTST	6.7	6.8	7.4	7.2	7.2	7.2	7.08
2	HB-C	6.5	6.7	7.0	6.6	6.1	6.7	6.60
	HB-HTST	6.4	6.6	7.3	7.4	7.2	7.0	6.98
3	HB-C	6.7	6.7	7.0	6.7	6.6	6.4	6.68
	HB-HTST	6.7	6.9	7.5	7.0	6.8	7.1	7.00
4	HB-C	6.7	6.8	7.1	7.0	6.6	6.6	6.80
	HB-HTST	6.8	6.6	7.6	7.4	6.9	7.5	7.13
Average	HB-C	6.65	6.75	7.03	6.80	6.40	6.65	
Average	HB-HTST	6.65	6.72	7.45	7.25	7.03	7.20	
Mean		6.65	6.74	7.24	7.03	6.71	6.93	

L. S. D. for stages in manufacture and storage ..... at 0.1 level = .20
L. S. D. for processes and lots ..... at .01 level = .22

[1] HB-C—Hot-break Conventional Retort Process.
HB-HTST—Hot-break High-Temperature-Short-Time Process.

Table 10 gives data for the average USDA color scores of tomato juice for the above two processes after 1, 5, and 10 months' storage.

The data in Table 10 were again contrary to results of Blumer *et al. (2)* who reported some discrepancy between visual color evaluations and color index values. USDA color score averages were not appreciably different either due to process or storage. This also agrees with the Munsell hue, value, and chroma renotation data discussed in Tables 6, 8, and 9 wherein it is shown that there were no significant differences between Munsell hue, value, and chroma renotation means of tomato

TABLE 10

USDA average color scores of tomato juice produced by the "hot-break" HTST and conventional retort processes after 1, 5, and 10 months' storage

Process	USDA color scores after storage		
	1 month	5 months	10 months
HB-C	28.5	28.0	28.0
HB-HTST	27.8	28.3	28.0

juice after 1, 5, and 10 months' storage. One exception, in the case of Munsell chroma renotations, was that only the chroma renotation mean of tomato juice samples after 5 months' storage was significantly lower than means of samples after 1 and 10 months' storage. There was no apparent visual difference, however.

Even though higher Munsell hue and chroma renotation means of canned tomato juice produced by the "hot-break" HTST process generally indicated a better color, average USDA color scores given in Table 7 show little difference when the canned tomato juice was evaluated visually. However, as was found in the case of the "cold-break" HTST and conventional processes, Munsell value renotations of tomato juice were significantly lower (darker grayness) for the "hot-break" conventional retort process. It is believed that here also, with respect to visual color, the lower Munsell value renotations of tomato juice produced by the "hot-break" conventional process nullified the effect of higher Munsell hue renotations and lower Munsell chroma renotation (indicating poorer color) more than was the case with tomato juice produced by the "hot-break" HTST process.

Thus, the necessity of taking into consideration the three attributes of the Munsell color system—hue, value, and chroma—is emphasized when attempting to relate objective color measurements in terms of Munsell hue, value and chroma to visual color evaluation.

CONCLUSIONS

In general, regardless of processing methods employed in this study for the manufacture of tomato juice, Munsell hue renotations of tomato juice increased (red toward yellow red change) during processing. Munsell value renotations increased (darker grayness to lighter grayness) and Munsell chroma renotation increased (increased brightness) due to the application of heat.

Summarizing the results concerning the "hot-break" and "cold-break" extraction methods presented in this study for the manufacture of tomato juice and the effect of the HTST and conventional retort processes, the data show little difference between the two heat preservation methods in terms of U. S. Department of Agriculture color scores assigned the canned product. It was also found that a lower Munsell value renotation of canned tomato juice results when using the conventional process for both "hot-break" and "cold-break" extraction methods. The lower Munsell value renotations (darker grayness) of tomato juice produced by the conventional retort process was believed to nullify the generally lower Munsell hue renotations (more redness) and higher Munsell chroma renotations (increased brightness) of tomato juice produced by the HTST process. In general, with regard to the effect of storage on the color of tomato juice there was no beneficial or detrimental change in color during 10 months' storage either in terms of Munsell hue, value, and chroma renotations or U. S. Department of Agriculture color scores of the finished product.

The results obtained re-emphasize the need for taking into consideration the three attributes of color—hue, value, and chroma—and clearly indicate the desirability of conducting further studies on the effect of each of these three attributes on visual color evaluation of tomato products.

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Sweet Corn Dehydration. I. The Falling-Rate Phase[a]

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The drying characteristics of partially dehydrated sweet corn in the falling-rate phase (T = 0.8 to T = 0.05) were investigated in a pilot plant through-flow drier. Variables studied included air temperature 110° F. to 180° F.), air velocity (50 to 250 feet per minute), air humidity (5% to 25% R.H.) and bed depth (2 inches to 8 inches). Rates of drying were followed by means of periodic moisture determinations. Principal variables in the dehydration process shown to have an effect were found to be air temperature and bed depth. Air velocity, in the ranges studied, had very little effect on the drying rate of sweet corn. Humidity proved to be an important factor only when the limits of the equilibrium moisture-relative humidity relations were approached.

Most work with dehydrated vegetables during World War II indicated a need for more effective means of reducing the moisture content of dehydrated vegetable products to very low levels. Improved product quality, increased storage life, and lowered tendency toward nonenzymatic browning were reported advantages to be gained.

One method of attaining a low final moisture content in the product involves extending the dehydrating conditions in such manner as to yield final products of low moisture content. Practically, product characteristics or dehydrator design and operating conditions were frequently found to be limiting. Among the more important factors were the conditions of controlled air flow, temperature, and humidity as well as such chemical or physical changes as discoloration and off-flavor development in the product. Obviously plant capacity was also involved.

Classically, the drying of moist solids may be divided into two or more distinct phases. In view of the findings mentioned above, there would appear to be considerable merit in studying sweet corn dehydration in several stages, or at least in the constant-rate and the falling-rate phase.

Previous workers *(1, 4, 5, 9, 12)* have studied various aspects of sweet corn dehydration and have concluded that the product offers possibilities as an acceptable dried food item. However, to assure the acceptability of dehydrated sweet corn, it was desirable to determine the optimum conditions of dehydration in the falling-rate phase. Knowledge of these conditions was felt essential to the attainment of a low final moisture content with a minimum of product damage.

Experiments described in this paper were directed toward determining the optimum conditions of through-flow dehydration of sweet corn in the falling-rate phase (T = 0.8 to 0.05).[c] The effects of temperature, humidity, and air flow on the rate of desiccation were studied under controlled conditions. Such data should be of value in establishing the upper limits of tempera-

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[c] T refers to the moisture ratio, pounds water per pound bone dry solids.

ture and humidity permissible at a particular moisture ratio that is consistent with retention of product quality. A companion paper will discuss the quality aspects.

MATERIAL AND METHODS

Apparatus. *Design of Drier.* An experimental, through-circulation, pilot plant dehydrator with suitable flexibility of control to give a wide range of dehydrating conditions with respect to temperature, humidity and air flow was designed (Figure 1). The heating unit, a, consisted of 2 finned-tube

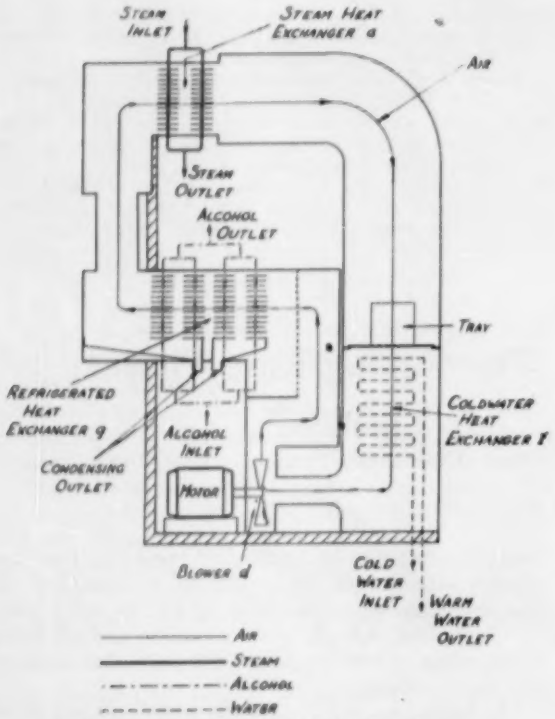


Figure 1. Schematic of pilot plant dryer.

steam heat exchange units placed in series and connected to the steam line through a pressure reducing valve. This arrangement permitted selection of steam pressures ranging from 10 to 100 p.s.i.g. Circulation of heated air was accomplished by use of a centrifugal fan, d, and air was drawn downward through product and tray.

Removable trays, of stainless steel and angle iron construction with bottoms of aluminum, 16-mesh, wire gauze, were used for holding samples to be dried. Trays, ranging from 0.25 to 4 square feet in area and from 8 to 36 inches in height were employed. A condensing system, f and g, was utilized in conditioning the drying air. The water cooled portion, f, was built of aluminum-finned copper coils. The refrigerated section, j, consisted of 4 finned-tube heat exchangers, similar to those employed in the heating unit and arranged on the discharge side of the fan. The drier door was fitted with a thermopane observation window and an outlet. A rubber sleeve was attached to the outlet to permit removal of samples without opening the door or interruption of drying.

Measurement and Control Equipment. Temperature control was effected by means of a motorized steam valve connected to a temperature controller. The copper sensing element of the controller was located in the center of the drier immediately above the upper surface of the drying bed and responded quickly to changes in drying air temperature.

Temperature measurements were made by use of copper-constantan thermocouples located in 12 important points within the drier. A strip chart recording potentiometer was employed to record the temperatures continuously.

Humidity control was effected by means of the condensing system or by steam injection. The condensing system consisted of a water cooled fin coil section to precool the air after passing through the drying bed and a refrigerated section. An alcohol-water solution, specific gravity 0.966, cooled by two compression type refrigeration coils, was circulated counter-currently through the refrigerated section to maintain desired temperatures at the condensing surface. Control was within ± 2° F. as measured by dew point determinations. In the case of runs requiring high relative humidity, steam was injected directly into the drying air.

Humidity was measured by adaptation of air dew point temperature determinations since it was felt that low air velocities would result in inaccurate wet bulb readings. A sample of the drying air was drawn through a specially constructed glass chamber containing a dew point hygrometer; the dew point was determined and the sample returned to the system. Measurement of air temperature leaving the cooling section was used as a means of checking dew point values.

Air velocity was controlled by a variable speed drive pulley on the fan motor. A wide range of air flow was available simply by varying the pulley size. After calibration against a pitot tube, a velometer was used for routine air flow measurement.

Operating procedure. In experimental operation, the sample was placed in position and the drier closed and sealed. Drying conditions were adjusted and maintained, as nearly as possible, constant throughout the drying run. The direction of air flow was downward through the sample bed. In this manner, uniformity of air distribution was attained and "blowholes" in the drying bed were avoided.

Raw material. Sweet corn of the Golden Cross hybrid variety was used in this study. It had previously been dried to approximately a T of 0.75 employing an air velocity of 300 feet per minute and using a drying schedule of the following conditions:

	Dry Bulb	Wet Bulb
	° F.	° F.
T_o to 1.5	200	120
T — 1.5 to T — 1.0	175	110
T — 1.0 to T — 0.5	150	105

Before initial dehydration, the corn was cut from cob, steam blanched for 2 minutes, dipped for one minute in a 1% sulfite solution, and drained for 5 minutes. Following initial drying, the partially dried material was placed in 30-pound tins, sealed and held in —40° F. storage. Prior to use in this study, all partially dried frozen material was mixed in the frozen state to insure as much uniformity as possible in the raw material. Immediately before drying, the samples were placed in a 34° F. room for thawing and ultimately allowed to attain room temperature before initiation of drying.

Fresh corn, as referred to in this paper, means corn that has been initially dried under the above schedule and then put directly into the drier for this study.

Analytical procedures. *Moisture.* The water content of sweet corn was determined by taking samples (a) of the initial material, (b) periodically throughout the drying run, and (c) of the final dry material. Moisture determinations were made upon these samples, ground in a Wiley mill to pass a 40-mesh screen, by drying for 16 hours in a vacuum oven at 70° C. under 15-16 mm. mercury pressure. Mean value of duplicate approximately two-gram samples was taken as the moisture content. "Apparent absolute moisture values" were then obtained by reading from a moisture correction chart. Data obtained by drying representative samples in a vacuum oven for 16, 35, 70 and 105 hours were checked against data for similar samples dried *in vacuo* over magnesium perchlorate at 100° F. for 3 months. Those data comparing most favorably with the magnesium perchlorate reference data were used in plotting the correction chart.

Rate of drying was followed by drawing samples at selected time intervals from the drying bed without interruption of drying. A rubber sleeve was designed in the door for this purpose. Samples were immediately sealed in screw cap glass bottles, allowed to equilibrate, predried when necessary, ground, mixed and used for vacuum oven moisture determinations. Final moistures were obtained from direct vacuum oven determinations on the suitably ground material.

This method of following the progress of drying was chosen in view of the small weight change (0.45 pound per pound) due to loss of water in going from a T of about 0.5 to a T of 0.05. Such a small loss makes weighing difficult, inaccurate, and of doubtful value in following the rate of drying. In the case of tray loading experiments, where quantities were large enough to permit accurate weighings and bed-depths were such that sampling for moisture determinations were likely to be inaccurate, the rate of drying was followed by periodic weighing.

Equilibrium Moisture. The equilibrium moisture-relative humidity relations of sweet corn were investigated in the region of 0 to 35% relative humidity by the method of Makower and Dehority *(10)*. Samples of sweet corn, ground to pass a 40-mesh sieve and previously dried for 10 months over magnesium perchlorate, were placed in all-glass vacuum desiccators. The desiccators served as constant-humidity chambers. Vapor pressure was controlled by means of aqueous sulfuric acid solutions of known concentration. The desiccators were then held in a constant-temperature cabinet at 100° F. so that the relative humidity within the desiccator was fixed. Water content of samples within the desiccator changed with time until equilibrium was reached as determined by weighing periodically until no change was observed over two weighings. Moisture content was taken as the difference between the weight at equilibrium and the initial weight of the completely dry samples. Empty glass weighing dishes were used as controls. Relative humidities were obtained by determining the specific gravity of the aqueous sulfuric acid solutions at equilibrium by means of a Westphal balance and reading the corresponding relative humidities from a suitable table.

RESULTS AND DISCUSSION

Collection of such fundamental information as the equilibrium moisture—relative humidity relations was felt to be requisite as a theoretical basis for this work.

Equilibrium relative humidity. Results of this study are given in Table 1. As pointed out by Makower and Dehority *(10)* and Gane *(6)*, the water relations of sweet corn in the range of humidities actually encountered under the conditions of drying will determine whether it is possible to produce a dried material of the required water content. From data presented, it may be seen that to obtain dehydrated corn of less than 5% moisture content requires a maximum of less than 30% relative humidity in drying air at 100° F. The economics of practical drying time suggest a much lower relative humidity than these limits in order to give vapor pressure differences or driving forces as large as possible.

TABLE 1
Equilibrium moisture content of dehydrated sweet corn at 100° F.

Relative humidity %	Moisture content %, dry weight
1	0.10
6	1.84
8	2.00
12	2.50
18	3.72
22	4.00
30	4.90
35	5.48

With these data available, study of the variables affecting the falling rate phase of dehydration was undertaken.

Reproducibility. A reproducibility test was designed to determine how closely drying curves would agree for similar material dried under identical constant drying conditions. It was found, when identical drying conditions were maintained, that the drying curves for drying runs of similar raw material and weight were in excellent agreement.

Air velocity. The air velocities tested in these experiments ranged from 50 to 250 feet per minute. During the course of drying, a slight increase in velocity usually occurred due to the slight reduction in resistance of the bed of sweet corn as drying progressed. However, this effect was not very pronounced as the bed remained uniformly distributed over the tray and did not exhibit any signs of cracking or shrinking from the sides of the tray.

The curves of drying time versus T value are shown in Figure 2. A slight time correction was necessary to account for variations in initial water content. This practice has been followed throughout this report and is in accord with techniques of other investigators. Gardner and Mitchell *(7)* demonstrated that drying curves of seaweed of different initial water contents were coincident when small corrections in drying time were made to account for this variation in water content. Brown and Kilpatrick *(10)* also encountered variation in initial moisture content when studying the drying characteristics of riced potatoes, and circumvented this difficulty by making small time corrections in order to base each test on a common moisture content.

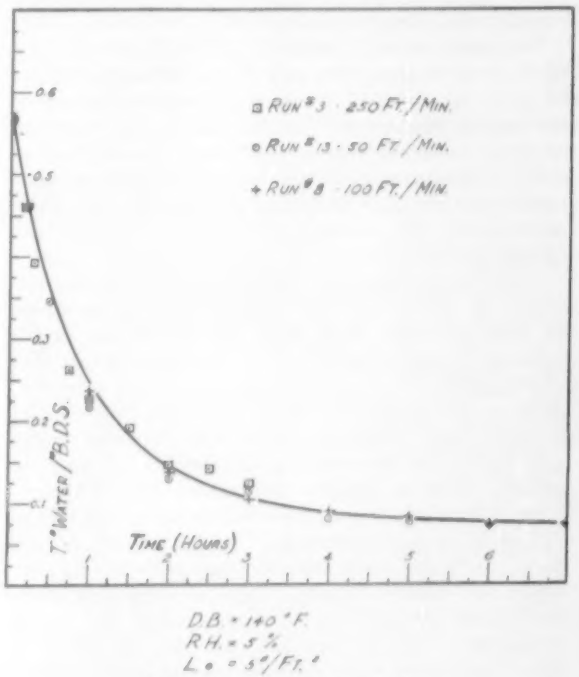


Figure 2. Effect of air velocity.

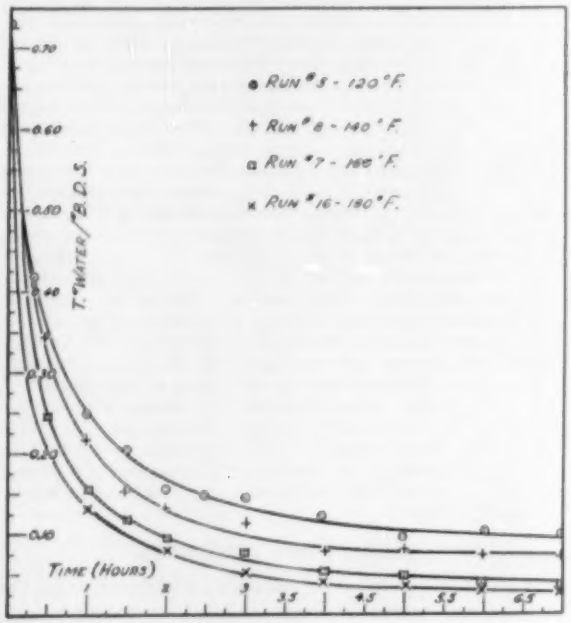
Figure 2 reveals that the effects of variations in velocity are so slight as to be of negligible consequence in the range of velocities studied (50 to 250 feet per minute) and in falling-rate phase of drying. Therefore, for subsequent tests, an arbitrarily chosen air velocity of 100 feet per minute was used.

These findings, relative to the effect of air velocity in falling-rate phase drying, are in substantial agreement with those reported in the literature *(8, 11)*. Mounfield *(11)*, in studying the drying of wheat in the falling-rate phase, found that the rate of drying was controlled largely by the rate of transference of water from the interior of the solid to the surface and became almost independent of such factors as humidity and rate of air flow. Hendry and Scott *(8)*, in discussing the fundamentals of air drying solids, point out that for a given surface-temperature and humidity condition the variation of evaporation rate with air speed will depend on the effect on the evaporation coefficient, K, as expressed by $K + (\text{velocity})^n$. They note that during the falling-rate phase the velocity index, n, must gradually decrease toward zero at the moisture content where velocity ceases to have an appreciable effect.

Temperature and humidity. A series of tests were designed to determine the effect of variations in relative humidity at constant temperature and variations in temperature at constant relative humidity. In one group of experiments, only the dry bulb temperature was controlled and relative humidity of the drying air was determined by the humidity of the atmosphere. For these experiments, tray loadings were set at 5 pounds per square foot.

Data showing the effect of variations in relative humidity at various constant temperatures are presented in Table 2. These data show that during the first 2 hours of drying some effects of variation in humidity of the drying air at constant temperature are apparent; this is especially true between the 5 and 25% relative humidity runs. However, in the low moisture ranges, any effects due to variation in humidity are less apparent. While it appears that moderate variations in relative humidity do not significantly affect the rate of drying in the moisture range T = 0.2 to 0.05, it must be borne in mind that these findings refer to comparatively low relative humidities and to conditions where the equilibrium moisture-relative humidity and dry air temperature relationships are such that the limits of these parameters have not been closely approached or attained. Insight into the effect of variation in temperature at constant humidity may also be gained from Table 2. At all constant humidities studied, an increase in drying temperature showed a marked increase in drying rate with a resultant decrease in drying time necessary to attain a particular moisture content in the dried material.

Drying time versus moisture ratio curves are given for the temperatures 120, 140, 160, and 180° F., which cover the range of temperatures likely to be employed in the drying phase under consideration. These data, shown in Figure 3, are useful in determining the elapsed time necessary to obtain a particular moisture content in the final product.



L. = 5"/Ft.²
V. = 100 Ft./Min.
R.H. = 5%

Figure 3. Effect of drying temperature.

Drying rates, pounds of water evaporated per hour per square foot, are another useful means of evaluating the effect of different temperature conditions. Drying rates for the same range of temperatures are plotted in Figure 4. The rates of drying curves were obtained by plotting the slope of the moisture ratio-time curves against moisture content. Data representing the first

TABLE 2

Effect of variations in relative humidity at constant temperature upon drying-time water-content relationships

Drying temperature °F.	120			140			160		
Relative humidity %	5	16[1]	25	5	12[1]	25	5	8[1]	25
Drying time (hours)	Moisture content pound water per pound B.D.S. (T)								
0	0.780	0.800	0.780	0.720	1.130	0.790	0.720	1.130	0.790
1	0.247	0.269	0.285	0.215	0.224	0.213	0.153	0.143	0.217
2	0.152	0.168	0.172	0.130	0.133	0.139	0.095	0.093	0.119
3	0.142	0.143	0.150	0.114	0.114	0.106	0.079	0.075	0.089
4	0.119	0.129	0.144	0.078	0.073	0.089	0.052	0.055	0.079
5	0.093	0.103	0.126	0.081	0.065	0.082	0.046	0.048	0.067
6	0.100	0.099	0.101	0.074	.....	0.066	0.041	.....	0.059

[1] Outside air used without any attempt to control the humidity during course of drying.

hour of drying is omitted in Figure 4 due to the fact that freezing, thawing and equilibration of moisture in these corn samples resulted in a somewhat different initial drying rate than would be expected from corn taken immediately from the preliminary dryer. Table 3 shows that fresh corn dried at a slightly slower rate in the initial phases of drying but differences in drying rate appear to level out as drying progresses.

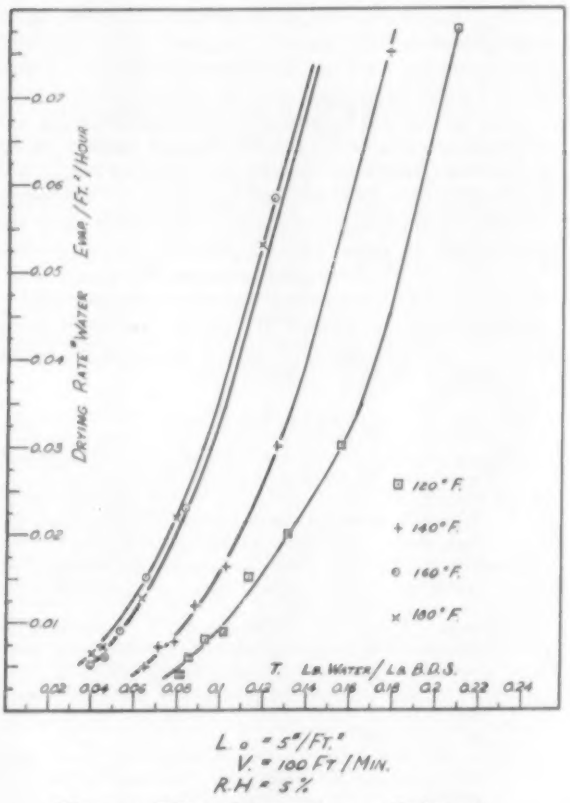


Figure 4. Effect of temperature on drying rate.

It is apparent from the data presented that temperature of the drying air is the major factor in rate of sweet corn dehydration in the falling-rate phase. Such results are in accord with the finding of other investigators *(3, 11)*. Undoubtedly the effect of temperature and moisture content are two primary factors in the falling-rate phase of drying where the characteristics of the data correspond to those of systems in which the rate of internal diffusion is controlling; that is, where neither air velocity nor humidity shows any appreciable effect. Many workers have advanced explanations for this phenomenon. Notable among these are the reports of Van Arsdel *(13, 14)* dealing with approximate diffusion calculations for the falling-rate phase of drying and making particular reference to vegetable drying.

TABLE 3
Comparative drying rates of fresh and partially dried frozen stored sweet corn

Temperature °F.	160		140		120	
Moisture ratio pound water per pound B.D.S. (T)						
Drying time (hours)	Fresh	Stored	Fresh[1]	Stored	Fresh	Stored
0	0.630	0.720	0.300	0.720	0.484	0.780
1	0.209	0.153	0.161	0.215	0.235	0.247
2	0.130	0.095	0.124	0.130	0.182	0.152
3	0.099	0.079	0.103	0.114	0.153	0.142
4	0.079	0.052	0.087	0.078	0.143	0.119
5	0.073	0.045	0.073	0.081	0.136	0.093
6	0.055	0.041	0.073	0.074	0.117	0.100

[1] Sample taken directly from preliminary drier while still hot.

Tray loading. Tray loading influences drier performance by lowering the drying rate and by causing a drop in the air temperature passing through the bed. Both effects result in a lengthening of the drying time and, consequently, affect the capacity of the drier.

In cross-flow drying, where relatively light tray loadings of wet material are employed, the initial rate of drying is quite markedly influenced by the tray load. Obviously, the drying air cannot penetrate very far below the surface of the bed and drying is thus prolonged.

In through-circulation drying much heavier tray loads are used because the air comes into contact with all the material in passing through the bed. Thus, the thickness of the bed becomes one of the important factors in this type of drying.

Dehydration runs testing the effect of tray loading were made employing wet-weights of 5, 10, 15 and 20 pounds per square foot. Drying time-moisture ratio curves are shown in Figure 5. The time required to dry sweet corn from an initial moisture ratio of 0.84 to 0.15 was plotted against the initial wet tray loading.

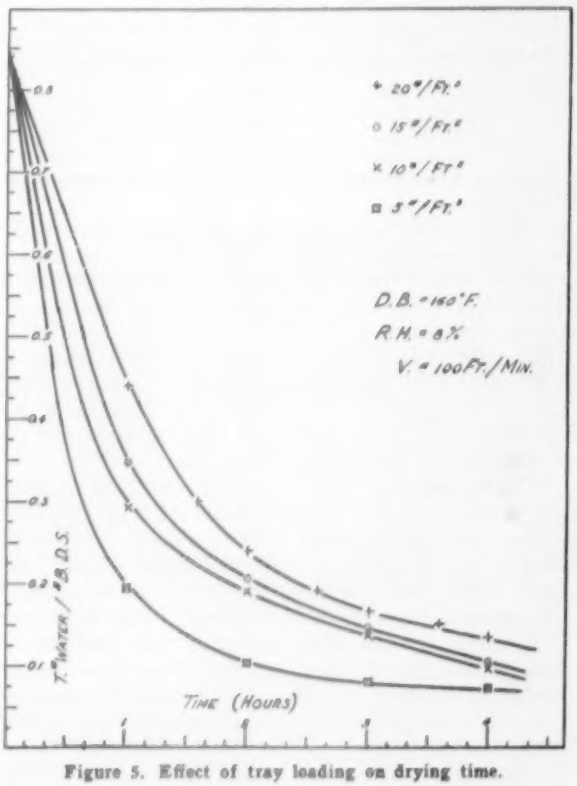


Figure 5. Effect of tray loading on drying time.

This curve (number one) is presented in Figure 6 and appears to be approaching a limiting value.

The output of dehydrated sweet corn (T = 0.15), starting at an initial water ratio of 0.84, is also shown in Figure 6. When output is plotted against wet loading

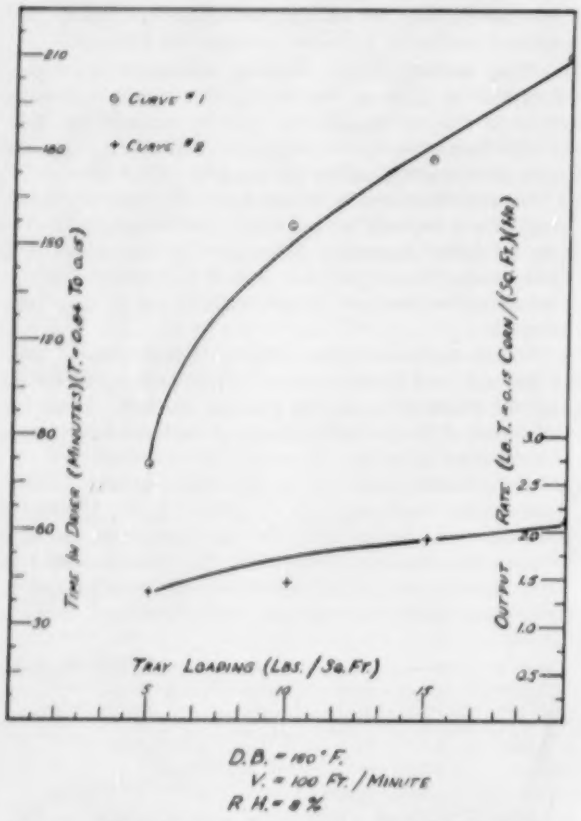


Figure 6. Effect of wet loading on drying time and output rate.

(curve number two), it is seen that, under these conditions, the maximum output is obtained with the deepest bed. It would appear that this curve is approaching a maximum or optimum value. However, further data on heavier tray loadings would be necessary to substantiate this point. One distinct disadvantage to deep beds is the fact that the longer drying time has an adverse effect upon the quality. This point is of paramount importance in connection with the total storage life of the product or its susceptibility to browning.

Static pressure drop. Data on the static pressure drop taken by the air as it is forced through the bed of sweet corn are important in drier design. The energy lost by the air increased as the bed depth of initial corn was varied from 2 to 8 in. At 20 ft./min. air velocity the pressure drop in the case of the 8-inch depth was 0.15 inches of water which was about twice that for the 6-inch bed. In the case of these depths, as the air velocity was increased above 60 ft./min. the pressure drop rose almost perpendicularly. A straight line was obtained when log mass air flow was plotted against log pressure drop for a one-inch bed of dried corn.

SUMMARY AND CONCLUSIONS

Results of experiments designed to study the drying characteristics of sweet corn in the falling rate phase (T = 0.8 to 0.05) have been presented. A pilot plant through-circulation drier was designed, built, and used for this study. Partially dehydrated samples of Golden Cross hybrid sweet corn with an initial moisture ratio of approximately 0.75 were the raw materials used.

Principal variables in the dehydration process shown to have an effect were found to be air temperature and bed depth. Air velocity and humidity, in the ranges studied, were found to have only slight effect upon the drying rate of sweet corn at moisture levels between T = 0.8 to 0.05. Humidity assumed importance when the limits of the equilibrium moisture-relative humidity relations were approached. Drying air temperature was shown to largely control the rate of drying in the falling rate phase of sweet corn dehydration.

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Sweet Corn Dehydration. II. Quality Effects of Falling-Rate Phase Drying Conditions[a]

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Final product quality was evaluated, by means of density, rehydration ratios, soluble color and organoleptic determinations. Soluble color value was shown to be a good indication of heat damage and proved to be a useful means of evaluating drying conditions. A highly significant correlation was obtained between soluble color and organoleptic score. From data obtained, it may be concluded that drying air temperature largely controls the rate of drying in the falling-rate phase of sweet corn dehydration and that selection of the drying air temperature in this phase of drying must be based primarily upon dried product quality with rate of drying assuming a secondary role.

Consideration of the finished quality of a processed food product is mandatory prior to recommendation of any set of processing conditions. This is particularly true with dehydrated sweet corn as drying conditions and final moisture content play major roles in determining final quality and storage life.

Properly dehydrated sweet corn has been reported to be an acceptable product *(1, 2, 5, 8)*. However, little information relating product quality to falling-rate phase dehydrating conditions is available in the literature. Since by far the greater portion of the drying time cycle is required in this phase of drying and, in addition, the product passes through the moisture content range thought most favorable for the occurrence of non-enzymatic browning, it seemed desirable to study the relationship between drying conditions and quality in the falling-rate phase of drying.

With these ideas in mind, changes in density, rehydration ratio, soluble color and organolepttic quality were used to study drying conditions from the standpoint of maximum or optimum drying rates and minimum product damage.

EXPERIMENTAL PROCEDURE

Density. Density determinations were made on the initial partially dried corn and upon the terminal samples of each dehydration run by means of a specially constructed apparatus. The essential features of the apparatus consisted of a container of known volume and a mechanical vibrator. Density calculations were made in terms of pounds of dehydrated corn per cubic foot.

Rehydration. The method of rehydration of the dehydrated corn used in this study was essentially that of Nelson *et al. (8)*. Rehydration ratios were calculated for the drying phase under consideration.

Soluble color. Soluble color determinations were made by using a modification of the method of Hendel *et al. (3)*. In essence, the method consisted of grinding samples of dehydrated corn to pass a 40-mesh screen, weighing duplicate 20-g. (M.F.B.) samples into 250 cc. Erlenmeyer flasks and covering with 200 cc. of distilled water. Samples were extracted for two hours with swirling at the beginning and at the middle of the extraction period. The supernatant liquid was decanted through Whatman number 12 filter paper at the end of the soak period. After combination of duplicate filtrates, 25 cc. aliquots of the filtrate were combined with an equal volume (25 cc.) of acetone to flocculate the colloidal starch particles. This solution was allowed to stand for 45 minutes, decanted into 50 cc. centrifuge tubes, and centrifuged for 5 minutes at 10,000 r.p.m. Following centrifugation, the clear supernatant liquid was decanted through Whatman number 40 filter paper and the pH of the filtrate adjusted to 5.7 ± 0.2 with approximately 2% acetic acid solution. Optical density was then measured with a Lumetron photoelectric colorimeter using a 420 mμ filter and a cell length of 18 mm.

Organoleptic testing. Organoleptic appraisal was made primarily to detect the effects of different drying conditions and was not a study of sweet corn quality per se. Organoleptic testing included the evaluation of four factors: natural flavor, color, texture and off-flavor in the manner employed by Nelson *et al. (8)*. The taste panel of experienced judges was comprised of staff members and graduate students. Factors of quality were graded on the basis of values ranging from 1 to 10, with 1 as *very poor; 5, acceptable;* and 10, *excellent*. Individual factors were averaged and summed to give average total score.

Stage drying. A limited number of "stage drying" runs were made by changing the constant drying conditions as dehydration progressed. Higher temperatures were used in the early stages while samples were still relatively moist. As the samples became drier, the drying air temperatures were adjusted downward in an attempt to avert excessive product damage. Such technique affords an insight into the relationship between drying rates and product quality.

RESULTS AND DISCUSSION

Density. Density measurements made upon the initial corn (with T value about 0.75, where moisture ratio, T = lbs. moisture per lb. dry solids) and upon the final dried corn samples did not show any definite trends ascribable to changes in dehydration conditions. Standard deviation among samples of similar material frequently exceeded any differences in density between samples prepared under widely differing drying conditions. It is interesting to note in Table 1 that little appreciable change occurred in density due to drying through the moisture range studied. Apparently the major changes in density due to drying occur well before the moisture ratios studied here are encountered.

Rehydration. Rehydration ratios were determined on the final samples of all dehydration runs. Changes in rehydration ratio did not appear to be a suitable index of quality changes. Study of Table 1 shows these data to be so scattered that no apparent correlation of change in rehydration with condition of drying, in the range of moisture ratios studied, may be found. This fact suggests that changes in rehydration ratio, in response to

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TABLE 1

Summary of soluble color, rehydration ratio, density and average organoleptic values as related to drying condition

Drying condition Air velocity 100 ft./min. unless otherwise specified. Tray load 5 lb./ft.[2] unless otherwise specified.							
Drying temperature ° F.	R. H. %	Drying time hours	Soluble color O. D.	Rehydration ratio	Density[1] lb./ft.[3]	Average organoleptic score	Final moisture %
140	5	2	0.020	3.231	33.07	32.2	12.1
140	5	3	0.021	3.401	33.65	30.7	10.6
140[2]	5	3	0.025	3.644	34.63	31.5	10.7
140	5	8	0.031	3.444	33.86	29.7	7.3
120	5	9	0.020	3.762	33.82	32.2	7.3
160	5	6	0.040	3.700	31.86	30.2	3.5
160	5	7	0.065	3.794	32.62	27.2	3.9
140	5	7	0.030	3.794	33.45	32.7	6.8
140	12	6	0.060	3.714	30.10	29.4	5.4
160	8	6	0.085	3.630	33.08	27.1	4.6
170	16	9.5	0.030	3.806	33.15	32.2	8.4
130	25	7	0.015	3.722	31.95	31.5	8.0
140[3]	5	8	0.035	3.764	33.15	32.7	6.7
140	25	7	0.020	3.702	33.06	31.0	5.7
160	25	7	0.060	3.626	35.50	27.2	5.6
180	5	6	0.205	3.540	33.98	18.7	4.3
160	8	4	0.065	3.536	30.46	29.4	6.7
160[4]	8	4	0.062	3.694	33.06	30.8	8.8
160[5]	8	4	0.060	3.578	34.69	30.1	9.4
160[6]	8	4	0.034	3.268	38.76	30.8	12.8

[1] Density of T = 0.79 corn was found to be 34.28 lb./ft.[3]
[2] Air velocity 250 ft./min.
[3] Air velocity 50 ft./min.
[4] Tray load 10 lb./ft.[2]
[5] Tray load 15 lb./ft.[2]
[6] Tray load 20 lb./ft.[2]

severity of drying conditions, reported by other investigators probably occurred as the result of effects more pronounced in the higher moisture ratio ranges.

Soluble color. So-called soluble color determinations have been applied to measuring the effects of time and temperature of storage upon quality of a number of dehydrated vegetables *(6, 7)*. On the basis of the fact that time-temperature effects in nearly dry vegetables are largely reflected in color change or the formation of brown color, soluble color measurement was adapted as an objective means of detecting reflections of drying conditions on product quality. Examination of soluble color values (Table 1) shows quite clearly that high drying temperatures resulted in the formation of brown color in the product.

A correlation of —.93 was found between objective soluble color values, reported in terms of optical density, and subjectively determined organoleptic scores. This correlation coefficient exceeded the value (.51) required for significance at the 1% confidence level. Results indicate a sharp increase in soluble color value when the approximate limit of palatability is approached. Tentative limits suggest inclusion of samples with an optical density of 0.100 or less in the definitely acceptable range.

The occurrence of "incipient heat damage" during the course of dehydrating vegetables has been reported by Hendel, Legault, and Talburt *(4)*. Observation made upon samples pulled during the progress of high temperature runs and upon the end samples of these runs, and subjected to brief accelerated high temperature storage studies, showed that the susceptibility to browning during storage was greatly increased. Samples dried under high temperature conditions browned much more rapidly and consequently attained the limit of palatability very quickly. Further evidence of heat damage by excessive temperature drying schedules was found by visual inspection of the drying bed during the course of high temperature drying runs. Signs of browning among scattered corn kernels in the bed began to be visually discernible in drying runs at 180° F. after approximately 3 hours of drying tmie had elapsed and, in the case of 160° F. runs, after about 4½ hours' drying time. Certainly, this is more than presumptive evidence that excessive drying temperature may precondition dehydrated vegetable material toward more rapid storage deterioration even though damage may not be apparent in the freshly dried material.

Organoleptic studies. Organoleptic appraisal of the terminal samples of each drying run showed a definite trend with respect to drying condition employed. The average total score of samples representing the drying runs are presented in Tables 1 and 3. Detrimental effects of high temperature dehydration runs were especially apparent on the individual quality attributes of natural flavor, color and off-flavor—with texture being affected to a somewhat lesser degree. Confidence in the organoleptic results was strengthened by the excellent correlation previously mentioned between average organoleptic scores and soluble color values. These subjective measurements indicate that damage to product quality, especially heat damage resulting from excessive drying temperature, is apparent at the conclusion of the drying run and tend to suggest that the limit of palatability for these products would be quickly reached in storage. In fact, prolonged drying at temperatures of 160° to 180° F. yielded products approaching or surpassing the limit of acceptability at the immediate conclusion of the drying run when the drying time was sufficient to reduce the moisture content to about 5%. From these results, it is apparent that drying conditions yielding an acceptable dried material

must be selected at the expense of some sacrifice in drying rate.

Stage drying. The idea of "stage drying"—the employment of a different set of drying conditions over selected moisture content ranges—has been advanced. Drying runs utilizing the schedules shown in Table 2

TABLE 2
Effect of temperature variation on rate of drying sweet corn by the stage method [1]

Drying schedule no.	1 160° F. — 2[2] 140° F. — 4 120° F. — 2	2 170° F. — 2 150° F. — 3 130° F. — 2	3 160° F. — 2 140° F. — 3 120° F. — 2	4 150° F. — 3 130° F. — 2 110° F. — 2
Drying time (hours)	Moisture content pound water per pound B. D. S.			
0	0.880	0.790	0.790	0.790
1	0.225	0.136	0.200	0.200
2	0.126	0.086	0.111	0.126
3	0.098	0.071	0.104	0.106
4	0.095	0.068	0.076	0.087
5	0.083	0.063	0.064	0.081
6	0.082	0.057	0.063	0.078
7	0.079	0.060	0.060	0.074
8	0.073	.....	.....	.....

[1] $L_0 = 5\#/ft.^2$, V = 100 ft./min., RH = 5%.
[2] The numbers refer to the drying time in hours at this temperature.

were made in an attempt to evaluate this possibility as well as to give some insight into possible temperature selection and choice of moisture ratio limits for the respective stages. Soluble color determinations and visual color observations were made to facilitate this selection by keeping recommendations amenable to quality considerations. These data are included in summary Table 3. Visible evidence of browning was be-

TABLE 3
Summary of soluble color, rehydration ratio, density and average organoleptic values as related to stage drying conditions.

Drying condition Air velocity 100 ft. per min., tray load 5 lb. ft.,[2] relative humidity 5%						
Drying temperature ° F.	Drying time at Spec. temperature	Soluble color O. D.	Rehydration ratio	Density lb./ft.[3]	Average organoleptic score	Final moisture %
	hrs.					
160	2					
140	4					
120	2	0.060	3.606	32.26	29.4	6.8
Total	8					
170	2					
150	3					
130	2	0.045	3.600	31.97	29.0	5.7
Total	7					
160	2					
140	3					
120	2	0.028	3.548	33.47	29.8	5.7
Total	7					
150	3					
130	2					
110	2	0.026	3.630	33.91	31.2	6.9
Total	7					

ginning to be noticeable after 7 hours of drying with schedule 1 and after 5 hours of drying using schedule 2. A plot of drying time-moisture ratio curves, after correction for initial moisture content variation, shows that curves for the various drying temperature conditions tend to converge after a moisture ratio of 0.15 to 0.10 has been attained. From the moisture range of 0.10 downward, excessively high drying temperatures are less advantageous from a drying rate standpoint. In addition, any advantage in rate of drying due to high air temperatures is more than offset by the damage to product quality.

In view of the effects of drying conditions, browning tendencies, tray loadings and temperature-time relationships, it would appear that division of the falling-rate phase of sweet corn dehydration into at least two and quite probably three stages would be advantageous both from a drying rate and product quality point of view. This statement appears justified from examination of runs in which constant temperature of 180 or 160° F. is used and the drying time prolonged until a low final product moisture is reached. Suggested stages would involve initial stages with moisture ratio limits of 0.7 to 0.15 to 0.06 and temperatures of 140 to 150° F.; and finally, the stage including moisture ratios of 0.06 downward and employing drying temperatures of 120 to 130° F. Tray loadings must necessarily be adjusted to the particular stage. Dehumidification of the drying medium appears to be an unprofitable practice in the initial stage, of doubtful practical value in the second stage, and an essential in the last stage especially if very low moistures are desired.

SUMMARY AND CONCLUSIONS

Results of an investigation of the effect of dehydrating conditions on product quality have been described. Soluble color value was shown to be a good indication of heat damage and proved to be a useful means of evaluating drying conditions. Organoleptic results were correlated with soluble color values and tentative limits of acceptability suggested. Density and rehydration ratio tests were found to be unsatisfactory measures of changes in product quality attributable to variations in dehydrating conditions over moisture ranges encountered here.

From data reported it may be concluded that drying air temperature largely controls the rate of drying in the falling-rate phase of sweet corn dehydration *(2)*, and that selection of the drying air temperature in this phase of drying must be based primarily upon dried product quality with rate of drying assuming a secondary role. Advantage may be gained by selecting temperatures according to stages of moisture content, which are in turn related to maximum drying rates consistent with product quality retention.

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Determinations of Enthalpies Involved in Food Freezing[a,b]

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A Dewar flask calorimeter was calibrated for use in the determination of enthalpy changes involved in freezing and thawing of several food products. Samples of approximately one pound were treated in a manner simulating commercial conditions. The experimentally determined enthalpy values were not significantly different from those calculated using data found in the literature. From an energy standpoint, freezing and thawing of foods yielded essentially the same results.

Several possible sources of error in applying theoretical values to commercial practice were discussed.

The commercial freezing of foods has become an increasingly important operation. As a consequence, research on the preservation of food by freezing has been greatly stimulated. Much study, for example, has been given to the energy exchange involved in the freezing process. However, the values reported in the literature appear to be greater, in certain cases, than those actually encountered in commercial practice. A number of frozen food producers have observed and reported a descrepancy as high as 20% between actual and calculated refrigeration requirements.

Enthalpy or heat content refers to the total amount of heat to be removed from a product in order to reach a reference temperature. Knowledge of enthalpy values is useful in the design of freezing installations as well as in the calculations of operation costs. Refinements in the calculation of enthalpy values are therefore of practical concern.

Published data on enthalpy values are based on calculations assuming a direct relationship between water content and the enthalpy of a foodstuff. Since this relationship was in question, there was a need to further check previous data. In making such an examination with laboratory facilities, it was necessary to simulate industrial operations experimentally as closely as possible. Among other things, this meant the use of relatively large samples of foods in nearly normal condition. Moreover, since previous enthalpy data were restricted to measuring the heat energy required to thaw a weighed sample of frozen food, it was of interest to determine whether enthalpy values were identical for both thawing and freezing.

The chief objective of this study was to achieve a calorimeter which would allow enthalpy calculations from freezing and thawing data. In so doing use was made of a normal size sample which would remain intact during the experiment and otherwise simulate the commercial production of frozen foods. This paper describes the calorimeter, summarizes the data obtained, and discusses the discrepancy between experimental and observed values.

Review of the literature. The first study of the specific heat of food products was conducted by Siebel in 1892 *(7)*. Siebel based his work and calculations on the assumption that there is a direct relationship between the water content of food and its specific and latent heats. He assumed that a food is largely composed of water and that its specific heat is equal to the weighted sum of the specific heat of water and the specific heat of the solid matter in combination with it.

In 1929 investigations into the thermal properties of foods were initiated at the University of Tennessee and continued for several years *(1, 8, 10, 11)*. The results *(11)* can be set forth as follows:

"a. The latent heat of fusion of fresh vegetables, fruits, meats and dairy products is directly proportional to the moisture content by weight.

b. The fusion points of foods are considerably depressed by the presence of starches, fats, and sugars.

c. Most foods have a freezing range of several degrees, extending from just below the freezing point of water to a temperature near 0° F.

d. The presence of any alcohol, by breaking down starches or sugars, lowers the fusion point.

e. The presence of fats, starches, sugars, and mineral salts has no measurable effect on the value of the latent heat of fusion of foodstuffs examined."

The linear relationship between moisture content and latent heat of fusion derived by Siebel gave accurate results for all foods tested. The study of the specific heat of foodstuffs was later continued at the University of Texas by Short and Woolrich *(5)* who improved the instrument developed at the University of Tennessee.

In 1944 Short and Bartlett *(6)* presented extensive experimental data as well as exhaustive mathematical and thermodynamic calculations on enthalpy changes of food products. The results obtained by their methods compared within 1% with previous data.

[a] This paper reports research undertaken with the financial assistance of The Refrigeration Research Foundation.

[b] Presented at the Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 15, 1955.

[c] Submitted by the senior author in partial fulfillment of the requirements for the M.S. degree in Food Technology, University of Illinois.

Riedel *(3, 4)* also investigated the heat content of foodstuffs. In his work on fruit and vegetable juices, he came to the conclusion that only the juice undergoes change of phase. Riedel paid considerable attention to the unfrozen portion of the water in the foodstuff at each specific temperature, and derived a method of finding enthalpies at any temperature from the solid content of the food.

In all studies discussed thus far, enthalpy measurements were obtained during a very slow rate of thawing of the foods. Ward *et al. (9)* showed that by rapidly freezing peanut butter a higher enthalpy value was obtained than by slow freezing. He ascribed this to unstable polymorphic crystal formation.

EXPERIMENTAL

Materials and methods. The materials used in this study consisted of ground beef, bananas, and carrots. Double distilled water was used to calibrate and test the instrument.

In order to avoid contact with the ethylene glycol solution used as a heat exchange medium in the calorimeter, all materials were sealed in tight containers. Polyethylene bags were used for the foodstuffs, since this material has a low heat capacity and exhibits good stability at low temperatures. The food was weighed directly into the bags. Two copper-constantan thermocouples were inserted into the food, one in the center of the product and the other one-third the distance between the center and the bottom of the bag. The package was then partially evacuated of air by means of a water aspirator, and the neck was tied with a wire. To prevent leakage through the neck, Duco Cement was applied in the neck opening, an additional wire was tied above the glued area, and more cement was applied above this tie. (Figure 1). Tin cans of the commercial

Figure 1. Containers with thermocouples.

type were used for the water in the calibration runs, since polyethylene bags would burst as the water freezes. A ⅛ in. hole was drilled into the lid of the can. After water was accurately pipetted through the hole, the hole was closed with a rubber stopper. Two thermocouple wires were passed through this stopper. The couples were placed in the same general position as that described for use with the food materials. After the stopper was in place cement was applied to prevent leaks. All cans and bags were weighed before and after each run; they did not show any change in weight.

All moisture determinations were made by vacuum oven drying at 160° F. and 29 in. vacuum for 24 hours.

Apparatus. A 24-liter, wide neck Dewar flask was adapted for use as a calorimeter. A 2-inch paraffined cork lid was fitted to the neck. The temperature measuring system consisted of copper-constantan thermocouples, a Type K2 potentiometer, a Model 4 Weston standard cell, and a Leeds & Northrup No. 2430-A galvanometer (Figure 2).

The liquid heat exchange medium in the calorimeter was a 60% solution of ethylene glycol in water. This solution was stirred by a constant speed Lightnin Model L mixer. The stirring was considered adequate in view of the fact that the difference in temperature between different points in the liquid did not exceed 0.05° C.

All experiments were carried out in an air-conditioned room at a constant temperature of 72° F. ± 1.0° F.

Experimental procedure. *Calibration.* Measurements were made to allow correction for the amount of heat exchanged between the heat transfer medium and its surroundings. A

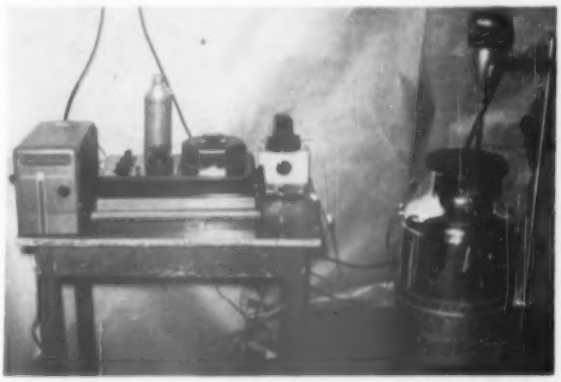

Figure 2. The calorimeter flask and the measuring instruments.

known weight of glycol solution at minus 35° C. was added to the Dewar flask and stirred while periodic temperature readings were taken.

From the resulting temperature vs. time curve (Figure 3), a graphical relationship between temperature and heat loss per unit was determined. This was done by plotting the slopes of tangents to the curve drawn at a number of temperatures against the respective temperatures (Figure 4). Thus, at any average temperature, for a given time interval, the rate of heat loss could be calculated by multiplying the change in temperature per unit time, as shown in Figure 4, by the weight of the glycol and its specific heat. The product of this rate and the length of the time interval gave the heat loss over this interval. The sum of

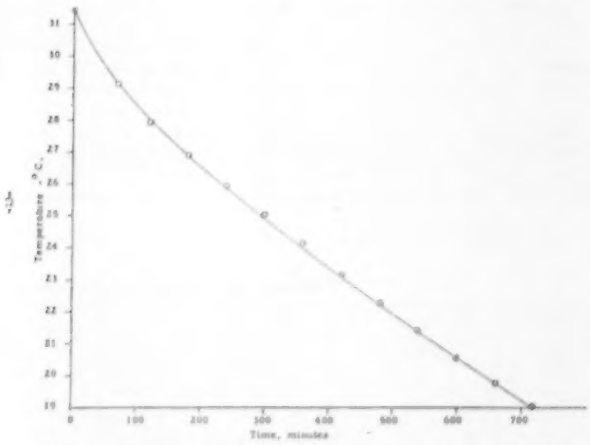

Figure 3. Change of glycol solultion temperature with time during calibration run 30.

the heat losses for all the intervals during the run gave the "calculated losses." Water was used to check this method of estimating the losses. The water can in each case was prepared 24 hours before the start of the experiment to allow the water to equilibrate to a constant temperature (72° F.). The can was then introduced into the cold glycol, and temperatures were recorded initially and periodically during the run. Final readings were taken when the temperature of the ice in the can approached the temperature of the glycol solution in the flask.

The difference between the experimental results and values

calculated from theoretical data available for water amounted to less than 1.0%.

In order to calculate losses during thawing in the same instrument the procedure was reversed. A known quantity of ice in the can was introduced into warm glycol solution. The theoretical heat required to thaw and warm the water was

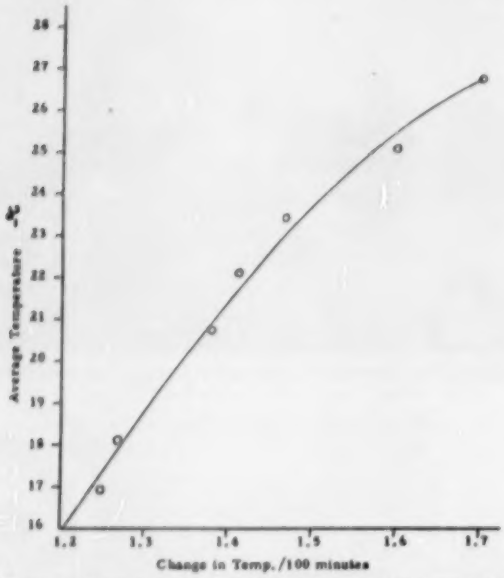

Figure 4. Heat losses, as indicated by rate of temperature change per unit time, as a function of temperature.

calculated and divided by the heat evolved from the glycol solution in order to obtain a loss factor. All factors obtained fell well within 2 standard deviations from the mean.

Enthalpy of food freezing. The food to be studied was put into the polyethylene bag (Figure 1) 48 hours before starting, to allow equilibration to temperature at 36° F. The experiment was not started until at least 4 hours after the glycol solution was placed in the calorimeter. Initial temperature of the glycol and food were recorded and periodic readings were taken. Final observations were made when the temperature of the two thermocouples in the product were not more than 0.5° C. apart. The procedure used for thawing was similar to that used for freezing. The difference was that the package was equilibrated at —20° C. and the heat exchange medium in the calorimeter was equilibrated at room temperature instead of at a low temperature.

RESULTS AND DISCUSSION

Duplicate experiments were performed on ground beef, banana puree, and grated carrots during both freezing and thawing of the same product. The results of these experiments are summarized in Table 1. The theoretical enthalpy values, shown in Table 1, were calculated by applying equations, taken from the Refrigeration Data Book *(2)*, to actual moisture determinations made on these foods..

The difference between the experimental and the theoretical values was divided by the experimental value to obtain deviation as shown in Table 1.. All experimental observations, both from freezing and thawing data, fell within ± 3% from the theoretical data. This deviation is within the limits of experimental error.

Using methods simulating industrial operation for enthalpy determinations, no real differences from previously established data were found. From these findings it seems reasonable to use an average value for the specific heat of food solids, for the foods tested, regardless of the composition of these solids. Furthermore, it was found that the thermal effect involved in freezing and thawing foods can be assumed to be essentially the same. There probably is some question in the instance of high fat content products and other special foods, but the variation is probably too small to be of commercial importance..

In order to find a possible explanation of deviations from theoretical data in commercial practice a brief examination of changes occurring during freezing was undertaken. Foods, unlike water, do not have a certain freezing point but rather a freezing range. For purpose of this discussion foods were thought of as a mixture of dry matter and water. This mixture exhibits the properties of a true solution with regard to the fusion point. The mixture starts to freeze at several degrees below 0° C., depending on composition. As some of the water freezes, the concentration of the mix-

TABLE 1

Summary of enthalpy calculations on three food products from freezing data

Run no.	Product	Weight of product Gr.	Weight of glycol Kgr.	Temp. rise glycol ° C.	Temp. change product ° C.	Total heat exchanged glycol K. Cal.	Calculated losses (Fig. 4) K. Cal.	Experimental enthalpy change of food K. Cal.	Theoretical enthalpy change of food K. Cal.	Percent deviation	Time of run Min.
57	Ground Beef	450	11.900	4.42	+ 1.85 —20.93	37.344	13.611	23.733	23.699	+0.18	118
58	Ground Beef	400	11.795	4.26	+ 1.99 —21.26	35.673	13.900	21.773	21.148	+2.9	119
59	Ground Beef	400	11.850	4.06	+ 2.20 —21.70	34.161	13.067	21.194	21.246	—0.7	110
64	Banana	300	11.830	3.72	+ 1.89 —20.86	31.244	9.776	21.466	21.702	—1.1	85
65	Banana	300	11.895	3.75	+ 1.26 —21.27	31.668	10.303	21.365	21.601	—1.1	87
68	Carrots	300	11.770	4.70	+ 1.42 —10.89	39.278	17.298	21.980	21.610	+1.7	144
69	Carrots	300	11.885	5.10	+ 1.98 —20.13	43.034	18.074	24.960	24.248	+2.8	154

ture increases and the freezing point is depressed further. The procedure continues until all the water has become ice. Short *(6)* showed that only at —40° C. is it safe to assume that all the water is in the ice phase. To illustrate this point the following example is offered:

PRODUCT: STRAWBERRIES OF 90.9% MOISTURE

Condition	Latent heat	Sp. heat above fusion point	Sp. heat below fusion point	Heat content at 42° F. (0° F. reference)
	Btu/lb.	Btu/lb./° F.	Btu/lb./° F.	Btu/lb.
All H_2O frozen	130.2	0.928	0.273	148.2
4.12% H_2O unfrozen	124.5	0.928	0.251	141.9

$$\text{Percent error} = \frac{148.2 - 141.9}{141.9} \times 100 = 4.5\%.$$

This example suggests an important corollary; namely, that in order to calculate the latent heat of a product the percent unfrozen water should be subtracted from the total moisture content. Neglect of this correction will give higher results than those obtained in commercial practice as illustrated in the example. The percent error will be even larger when strawberries with added sugar are frozen, as is normal commercial practice.

Another source of considerable error in commercial calculations may be the assumption of an incorrect moisture content. All published values are average moisture values. On the other hand large variations of moisture content in the same product will occur depending on variety, growing conditions, maturity, and so on. Also, as another source of possible error, in the advanced stages of ripening some carbohydrate conversion to alcohol may occur. For example, the published latent heat of 74% moisture sweet corn is 106 Btu/lb. However, the moisture content of sweet corn will often vary as much or more than 10%. If sweet corn of 64% moisture content (actual) is assumed to have 74% moisture, the error caused may be considerable. Thus:

FRODUCT: SWEET CORN OF 64 VS. 74% MOISTURE

Percent moisture	Latent heat	Sp. heat above fusion point	Sp. heat below fusion point	Heat content at 42° F. (0° F., reference)
	Btu/lb.	Btu/lb./° F.	Btu/lb./° F.	Btu/lb.
74	106.0	0.792	0.422	127.4
64	91.7	0.712	0.392	111.3

Percent error = 14.5%

The theoretical calculation shows an enthalpy almost 15% greater than would be found in practice. So substantial an error is worthy of concern.

In commercial operations it is difficult to estimate correctly the average temperature of the product as it is frozen. Equilibrium temperature of bulky products is not reached until several hours or even days have passed. Sometimes lower temperatures are assumed to be reached than is actually the case. This can be illustrated by assuming that operational conditions call for freezing of the entire product to 0° F.; actually an average temperature of only 10° F. is reached. Frozen peas of 80.0% moisture can be used as an example:

PRODUCT: FROZEN PEAS OF 80% MOISTURE

Temp.	Unfrozen water %	Latent heat	Sp. heat above fusion point	Sp. heat below fusion point	Heat content at 42° F. (0° F., reference)
		Btu/lb.	Btu/lb./° F.	Btu/lb./° F.	Btu/lb.
0° F.	2.65	111.0	0.84	0.43	133.2
+10° F.	6.20	105.8	0.84	0.42	123.4

Percent error = 7.9%

Here the value calculated on the false premise of 0° F. final temperature was 8% too high.

The above examples show that a variation of 20% or more between commercial observations and published data is possible.

SUMMARY

A new approach to the determination of enthalpies involved in food freezing was studied. A Dewar flask calorimeter was assembled, tested, and found to be satisfactory. The instrument was calibrated to measure energies involved in freezing and thawing of several food products. Samples reflected commercial sizes and they were treated in a manner similar to that used under commercial conditions.

The results of the experiment showed that for the foods studied there was no real difference between the calculated values from the literature and the experimental data. It was also established that from an energy standpoint freezing and thawing of foods was essentially the same. However, in calculating the enthalpy of a food product from available published data for commercial application the following conditions should be observed:

a. The exact moisture content of the specific food should be known.
b. Allowances should be made for the unfrozen portion of water.
c. Average temperature of the product, before and after cooling or freezing should be established with reasonable accuracy.
d. The freezing method employed should be studied for congruence with experimental method.

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Interactions Between Ascorbic Acid and Psychrophilic Bacteria Associated With the Discoloration of Prepackaged Beef[a, b, c]

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(Manuscript received June 21, 1955)

The effect of ascorbic acid on psychrophilic bacteria associated with discoloration of meat is reported. The influence of these bacteria on ascorbic acid is noted. The possible maintenance of a bright red color in prepackaged beef by ascorbic acid treatment was investigated but was shown to be a less important factor than keeping the initial bacterial contamination low.

A number of factors have been shown to contribute to the discoloration of fresh prepackaged meat, but one of the principal causes is the growth of psychrophilic bacteria *(2)*. Recent work *(3, 9)* indicates that ascorbic acid will delay surface darkening of meats for some time. This has been attributed to the reduction of metmyoglobin or methemoglobin *(3, 10)*. However, preliminary studies in our laboratory indicated that strains of *Pseudomonas* sp. were inhibited by ascorbic acid. Myrvik and Volk *(7)* recently reported that ascorbic acid was inhibitory to another strain of this same genus.

A comprehensive review of the interactions between ascorbic acid and bacteria has been made recently by Eddy and Ingram *(4)* and will not be repeated here. However, to sum up their review, it has been reported that ascorbic acid may stimulate the growth of some bacteria and inhibit the growth of others. At the same time, some bacteria may have no influence on ascorbic acid, some may protect it again oxidation, while still others may decompose the acid.

The purpose of this study was to determine the effect of ascorbic acid on psychrophilic bacteria associated with the discoloration of meat and the influence of the bacteria on ascorbic acid. Finally, the relationship between bacterial growth and ascorbic acid treatment of prepackaged beef as to the maintenance of a bright red color was investigated.

METHODS

Source and handling of test cultures. Two strains of *Pseudomonas sp.* (No. 1 and No. 2) known to cause discoloration of fresh beef were used in this study. They were the strains used by Butler *et al. (2)* and were obtained originally from the American Meat Institute Foundation, Chicago.

The cultures were maintained on nutrient agar (Difco) slants and 24 hour cultures prepared for inoculation purposes.

Determination of the effect of ascorbic acid on the growth of Ps. sp. A 1% ascorbic acid solution was prepared in sterile distilled water and 1 ml. of this added to 9 ml. of sterile nutrient broth to give a 0.1% concentration of ascorbic acid. The pH of the nutrient broth was 6.9 and that of the broth with 0.1% ascorbic acid was pH 5.1. A control flask of nutrient broth adjusted to pH 5.1 was subsequently run to check for inhibition due to pH.

A one ml. inoculum of a 24-hour nutrient broth culture of each strain was added to each of two flasks of nutrient broth (100 ml./flask) and into two flasks with added ascorbic acid. One series of flasks was incubated at 4-7° C. and the other at room temperature (22-23° C.).

Standard plate counts were made at intervals during a period of 5 days using tryptone glucose extract agar (Difco). Quadruplicate plates of each dilution were incubated at both room temperature and 4°-7° C. The plates at room temperature were incubated for 2 days and those in the refrigerator for 7 days.

Determination of the effect of Ps. sp. on ascorbic acid. Six flasks of nutrient broth (100 ml./flask) containing 0.1% ascorbic acid were prepared as described in the preceding section. Two flasks were inoculated with each strain of *Ps.* sp. and one incubated at 4°-7° C. and the other at room temperature. An uninoculated control flask was, also, incubated at each temperature.

Assays for ascorbic acid and for total vitamin C-like compounds represented by ascorbic acid, dehydroascorbic acid and diketogulonic acid were run initially and after 1, 3 and 5 days incubation. The indophenol xylene extraction method was used for ascorbic acid and the dinitrophenylhydrazine method for total vitamin C-like compounds. The procedures used were outlined in *Methods of Vitamin Assay (1)*.

Determination of the effect of ascorbic acid on the color and on the growth of bacteria on the surface of prepackaged beef steaks. Steaks were cut from the *longissimus dorsi* muscle of beef from the lumbar region. They were sliced about ½-inch in thickness with a sanitized slicing machine. By maintaining the steaks in the order of cutting, it was possible to pair the matching surfaces for treated and untreated samples. Sufficient steaks were cut to have one steak per treatment to sacrifice for each period of examination for bacteria and fading index.

Four ascorbic acid treamtents were tested; *viz.* (a) dipping the steaks in a 1% ascorbic acid solution made in sterile distilled water for 15 seconds (b) dipping in this solution for 30 seconds, (c) spraying with a 1% solution by use of an atomizer, and (d) direct application of ascorbic acid with a pepper shaker. The first 3 methods gave similar results but the direct application resulted in immedite discoloration of the surface. Therefore, the spraying technique was employed in the majority of the experiments because it is more sanitary and easier to estimate the amount of ascorbic acid added. The average amount of the 1% solution added to 48 steaks was 1.39 g. of the 1% solution per steak or about 0.014 g. of ascorbic acid.

All steaks were wrapped in Du Pont 300MSAT No. 80 cellophane.

The method of Nickerson *(8)* was used for the measurement of color of the steaks by the use of Munsell spinning disks. The index of fading was calculated using the standards suggested by Butler *et al. (2); viz.* hue 7.0; value, 4.0; and chroma, 8.0.

Two methods of sampling for bacteria counts were tested; the swab method using a stainless steel plate with a one-inch square cut-out was compared with the slicing technique employed by Butler *et al. (2)*. The latter technique gave more consistent results and was used in these experiments.

RESULTS

Effect of ascorbic acid on the growth of Ps. sp. The addition of 0.1% ascorbic acid to nutrient broth had a pronounced in-

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[b] This work was partially financed by a grant from Merck and Company, Rahway, New Jersey.

[c] Presented at the Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 14, 1955.

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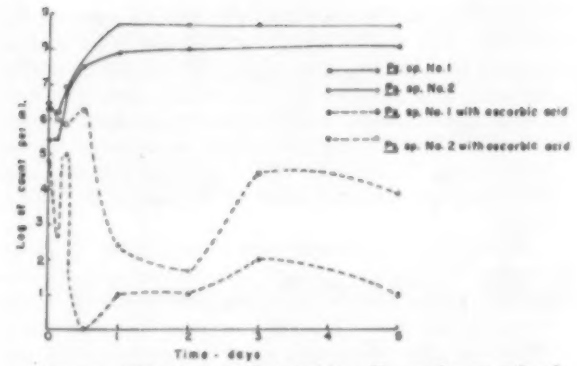

Figure 1. Effect of 0.1% ascorbic acid on the growth of two strains of Pseudomonas sp. in nutrient broth at room temperature.

hibitory effect on the two strains of *Ps.* sp. tested (Figure 1). The results obtained at both room and refrigerator temperatures were quite similar. There was always some increase in the populations of both cultures in the ascorbic acid medium after 2 days' incubation, but they never attained the magnitude of the original inocula.

This inhibition was not due to the relatively low pH of the ascorbic acid medium (pH 5.1), as proven by growth in nutrient broth adjusted to the same pH with hydrochloric acid.

Effect of Ps. sp. on ascorbic acid. The influence of the two *Ps.* sp. strains on the ascorbic acid added to the medium was very interesting. Little or no effect was noted when the inoculated medium was incubated at refrigerator temperatures. However, when incubated at room temperature, both strains of the organism were found to influence the rate at which ascorbic acid disappeared from the medium. Thus, after the first day of incubation, the ascorbic acid content of the uninoculated medium was reduced more rapidly than that of the inoculated broth (Figure 2). After 5 days' incubation, the ascorbic acid concentration of the control medium was less than 50% of that in the inoculated.

Since a great loss in ascorbic acid was noted in the medium during incubation, it was deemed desirable to check on the extent of oxidation which occurred. Therefore, assays were run for total vitamin C-like compounds including ascorbic acid, dehydroascorbic acid and diketogulonic acid.

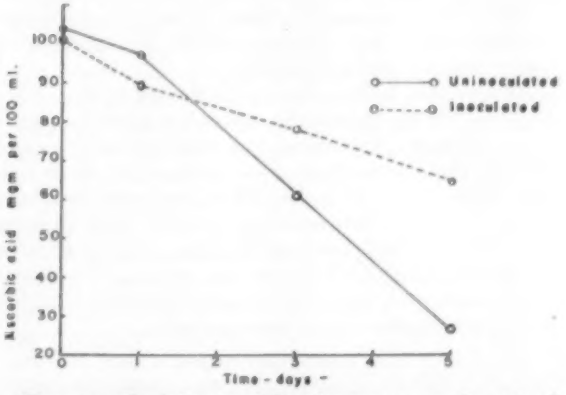

Figure 2. The influence of Pseudomonas sp. on the rate of oxidation of ascorbic acid in nutrient broth.

As might be expected from the earlier studies there was very little loss of the total vitamin C-like compounds during 5 days' incubation at refrigerator temperatures in either the control or inoculated medium. Somewhat greater reductions were noted at room temperature than at refrigeration temperature, but there was no significant difference between the control and inoculated samples (Figure 3). Therefore, while the organism apparently protected the reduced form (ascorbic acid) from oxidation it did not protect the diketogulonic acid from oxidation.

Effect of ascorbic acid on the color and on bacterial growth on the surface of prepackaged beef steaks. A number of preliminary experiments indicated that ascorbic acid delayed the discoloration of the surface of beef steaks for a variable period of time. The effect was not noticeably different when the steaks were dipped in a 1% ascorbic acid solution for 15 seconds or 30 seconds or when they were sprayed with the solution by use of an atomizer. However, sprinkling with the dry powder with a pepper shaker resulted in immediate browning of the entire surface covered.

Five replications were made of an experiment comparing ascorbic acid treated and untreated paired steaks as to rate of discoloration and bacterial populations. Five additional experiments were run comparing treated and untreated paired steaks inoculated with *Ps.* sp. No. 1 with treated and untreated, paired, uninoculated steaks. All steaks were held at 4-6° C., except for two experiments comparing inoculated and uninoculated steaks where they were refrigerated in a self-service case having a surface temperature of about 4° C.

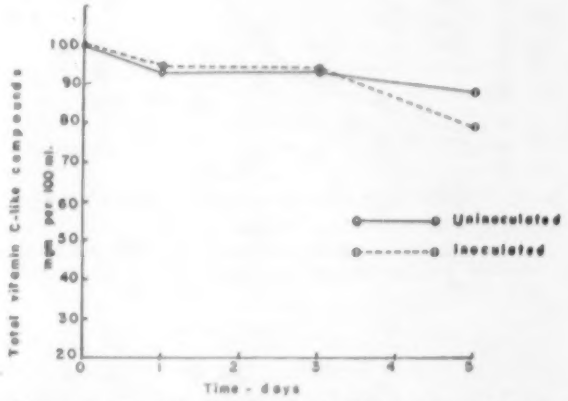

Figure 3. The loss of total vitamin C-like compounds from inoculated and uninoculated nutrient broth.

The results of all experiments were similar in that there was absolutely no measurable influence of ascorbic acid on the growth rate of bacteria on the meat surface. Also, the ascorbic acid treated steaks were usually slower to start to discolor than the untreated. However, this delay only amounted to about a one-day period and was not always in evidence. When the treated steaks started to discolor, they did so quite rapidly.

The ascorbic acid treatment was not as important a factor in the preservation of color as was the maintenance of low bacterial numbers. As may be noted from the results of a representative experiment given in Figure 4, the inoculated steaks browned much more rapidly than the uninoculated. Visual examinations showed that the inoculated steaks were all discolored badly after from 3 to 4 days of refrigeration while the uninoculated groups maintained a satisfactory color for 7 or 8 days. In no instance did the ascorbic acid delay the discoloration for more than 1 day and in case of some of the paired steaks the treated steaks browned as rapidly as the untreated. It can be noted in Figure 4, that on the days that color measurements were taken there were no significant differences between the fading indexes of the ascorbic acid treated and untreated steaks of each lot. However, visual observations indicated that differences might have been obtained if readings had been made on the third and seventh day.

The results of the studies on steaks refrigerated in the household type refrigerator and those in the self-service meat case were quite similar.

DISCUSSION

Ascorbic acid in 0.1% concentration was found to have an inhibitory effect on two strains of *Pseudomonas*

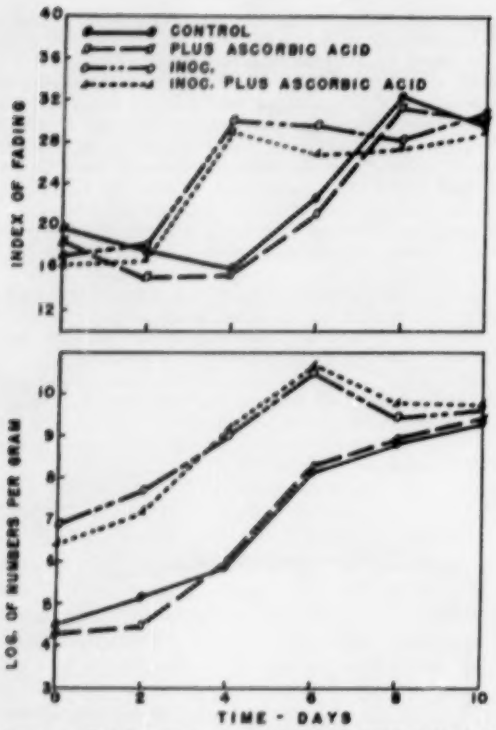

Figure 4. The influence of ascorbic acid treatment on color retention and the rate of bacterial growth on the surface of beef steaks.

sp. tested. Since these organisms prefer aerobic conditions, a possible explanation for this inhibition is the reduction in O/R potential of the medium by ascorbic acid. However, these organisms are somewhat facultative to oxygen and, therefore, one would not except them to be inhibited to the degree noted here by this action. Other possible reasons for the inhibition of microorganisms by ascorbic acid suggesed by Eddy and Ingram *(4)* were the increase in acidity and the release of hydrogen peroxide in the medium. Myrvik and Volk *(7)* proposed that the antibacterial properties were due to breakdown products of auto-oxidized ascorbic acid rather than to the acid *per se*. It is also plausible that ascorbic acid might cause inhibition in the same manner as other organic acids.

The two strains of *Ps.* sp. tested were both shown to slow the rate of oxidation of the reduced form of ascorbic acid. Esselen *(6)*, also, noted that bacteria of this genus had a protective or sparing action on the acid. Ehrismann *(5)* noted that resting cells would protect ascorbic acid but that actively growing cultures would not. The most probable explanation for this protection is the reduction in oxygen tension of the medium by the organism with a resultant decrease in O/R potential. However, the two strains of *Ps.* tested did not apparently influence the rate of disappearance of the total vitamin C-like compounds in the medium.

When ascorbic acid was added to meat, there was no measurable effect on the growth of bacteria on the surface. The difference between the results obtained on meat and in nutrient broth may be due to one or more of the following factors: (a) the concentration of the ascorbic acid on the meat surface would be rapidly reduced to much less than 0.1%, (b) the meat buffered the solution at a higher pH than that in nutrient broth, (c) it may not have been possible for the ascorbic acid to reduce the O/R potential of the meat surface to the same extent as nutrient broth, (d) the ascorbic acid may have been rapidly oxidized by substances in the meat.

The addition of ascorbic acid to beef steaks either by dipping the steaks in a 1% solution or spraying the solution on the surface usually resulted in a delay in the discoloration rate. This was as expected from previous reports *(3, 9)*. However, when the ascorbic acid was added by sprinkling on the surface, immediate discoloration occurred and the surface remained dark through several days refrigeration. Watts and Lehmann *(10)* noted that hemoglobin solutions were turned a green color by high concentrations of ascorbic acid due to choleglobin formation, but no evidence of any green color was noted on these steaks. They turned a brownish-red color in a very few minutes after the addition of the acid, indicating that the pigment had been oxidized to metmyoglobin directly. Thus, as previously suggested *(3, 10)*, the concentration of the ascorbic acid on fresh meats is of great importance.

Although ascorbic acid aided in the maintenance of a bright red color on prepackaged meat, it was not nearly as important a factor as the bacterial growth. This work substantiates that of Butler *et al. (2)* showing that the rate of discoloration is very dependent on the activity of bacteria. Ascorbic acid may make a difference of a few hours, while the difference between heavily contaminated and lightly contaminated steaks may amount to 3 to 4 days.

SUMMARY

The addition of 0.1% ascorbic acid to nutrient broth was shown to prevent the growth of two strains of *Ps.* sp. for several days. At the same time the presence of the bacterial cells protected, in effect, the ascorbic acid from oxidation but had no influence on the concentration of total vitamin C-like compounds.

When added to the surface of fresh beef steaks, ascorbic acid did not measurably affect the growth of bacteria. However, the use of low concentrations usually delayed the discoloration of the surface for about one day. This effect was not consistent and often there was greater variation between lots of steaks than between treatments. It was demonstrated that a desirable color would be maintained longer by keeping the initial bacterial contamination low than by treatment of highly contaminated steaks with ascorbic acid.

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Nutrition Education—Opportunity and Responsibility[a]

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The extension of knowledge that increases nutritional awareness—the objective of nutrition education—represents both an opportunity and a responsibility for all of us.

Our nation has learned much about the production of food. Scientists engaged in nutrition research have made good progress toward better understanding of the relationships between food and health. The cooperation and support of the food industry has made it possible to put into effect many important dietary improvements representing major contributions to the health of our people. Vitamin D fortified milk, enriched and restored cereal products, and iodized salt are well-known examples of such measures.

That the technologists of the industry have the responsibility for reducing these programs to practice is known to industrial and technical groups although it is not well recognized by the public.

FOOD TECHNOLOGISTS CAN MAKE AN IMPORTANT CONTRIBUTION

Food technologsts and scientists have another important part to play in the public service. Besides their contributions in food research and technological development, their active participation in nutrition education programs is called for wherever and whenever possible. The fact that the general public has yet to learn how to use the food available for the greatest common good is a strong argument for wider and more effective dissemination of sound and reliable nutrition information.

We have a so-called "food surplus" situation in the United States, illustrated by Government storage of 6 to 7 billions of dollars worth of farm products. At the same time we find in every section of the country where reliable food consumption surveys have been conducted, that from approximately one-third to one-half of the individuals have been consuming diets that did not furnish, regularly, the quantities of individual nutrients that meet the recommendations of the nation's leading authorities on human nutrition. Enough of the right food is at hand and family budgets show that enough money is spent to accomplish good nutrition for all, but we continue to have great waste, both human and economic, because of lack of knowledge of how and what to eat. This situation presents all of us with an unusual opportunity and a social responsibility.

Certainly there is a growing public impression that there are definite benefits to be derived from better nutrition. The consumer wants to know more about the ways in which food habits may affect his health and well-being. This attitude provides a highly favorable situation for contributing to the betterment of life in the United States through a program of education aimed to improve our eating habits.

The natural tendency of the consumer to accept statements and claims that seem plausible on the basis of his knowledge and experience presents a hazard, however, because public education in nutrition as yet has not been sufficiently extensive to enable the consumer to distinguish readily between reliable and unreliable information.

If our people are to be properly informed, those who have related professional training must take the responsibility for solving the problem of reaching the public with more nutrition information. Undoubtedly food technologists are willing to accept their fair share of that responsibility. Particularly qualified both as scientists and as representatives of industry to aid in any such educational effort, food technologists can make an important contribution toward providing the leadership and guidance needed to carry an effective nutrition education program to the public.

The public and the food industry have much to gain from a broader understanding and more extensive application of our present knowledge of nutrition.

WE ARE FAR FROM OUR NUTRITIONAL GOAL

Many signs point to the prevailing need for increased public education in nutrition. Observations made on both rural and urban groups in various areas continue to show that although progress is being made toward improvement of our nutritional levels, we are far from our nutritional goal. Reference to a few of these findings may serve as an illustration, and to point up the

[a] Presented at the Fifteenth Annual Meeting of the Institute of Food Technologists, June 12-16, 1955, Columbus, Ohio.
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fact that for the most part the conditions found could be attributed to poor food habits subject to improvement through an adequate educational program.

In Iowa, where the population has the reputation of being well fed, some nutritional faults were indicated by a recent study of the diets and general state of nutrition of school-age children *(4)*. Since in a group of over 600 children more than half had diets which were inadequate when checked against the recommended dietary allowances of the National Research Council Food and Nutrition Board, the Iowa study points to the need for statewide nutrition education programs to bring about an improvement in the diet of school children.

In Virginia a survey of a typical rural area showed three groups of foods to be seriously lacking in the diets of more than half the families: tomatoes, citrus fruits, and other good food sources of vitamin C; milk and milk products; and green and yellow vegetables *(5)*.

In a similar study of some 250 farm families in Minnesota, one-third of the households had diets that failed to meet the 1948 National Research Council recommendations for calcium and vitamin C, and about one-sixth had diets that failed to meet the recommended allowances for vitamin A, thiamine and niacin *(3)*.

A Rutgers University survey of a large group of male industrial workers showed that many of the men were not eating three nutritionally balanced meals daily *(1)*. Other studies have shown this to be true also of teen-age girls, working women, and women worried about their weight. Breakfast is the meal most often neglected.

The Rutgers survey showed that the diets of about one-fourth of the men were low in calcium and vitamin C, shortages of thiamine and riboflavin were found, and yet almost half of the men were overweight. The men with nutrient shortages were not eating enough of the protective foods. The overweight men were slighting breakfast and then easing mid-morning hunger with high calorie snacks so that at the end of the day they may have consumed more calories than if they had eaten a heartier breakfast.

The latest nation-wide survey of diets of urban families indicated that only 60 to 70% of the survey families had diets providing calcium at recommended levels *(2)*. About 80% had diets providing recommended amounts of vitamin C, thiamine, riboflavin, and niacin.

WHERE AND HOW TO ASSIST

The fact that a majority of our people look to the professional groups for information upon which they can rely furnishes one of the best possible reasons for professional scientists to assume more public responsibility for spreading sound nutrition information.

If we choose to assume our share of the responsibility for wider dissemination of nutrition information, we must then decide where and how this can best be done. As to *where*, perhaps it is sufficient to note that one of our leading public health authorities has said that no community is sufficiently free of malnutrition to be complacent. There is no lack of opportunity, also, from the standpoint of *how*, to find ways to assist in educational work. Nutrition education of communities and individuals can be accomplished through attractive literature, the press, radio and television, films, demonstrations, and by stimulating cooperative programs with local organizations. Food technologists acting as a group and individually can play an important part in all such activities.

Activities in the community could include encouragement of nutrition education programs under way in schools at all levels from kindergarten up and participation in organized efforts to have such programs introduced in schools that do not have them. In the same way nutrition classes for adults and recommendations that the systematic teaching of nutrition be included in the professional training of teachers, doctors, dentists, nurses, public health and social workers, and home economists should be supported.

A check of the books used in the schools and available in the libraries is well worth while. It is not uncommon to find, for example, that the approved list for high schools includes a popular author's well-publicized, inaccurate book purporting to be a guide to nutrition. The library shelves may carry the latest effort of a widely advertised food fad writer, but will have a 1922 edition of one of the recognized standard texts on foods and nutrition.

Professional groups can be highly effective in organizing and arranging meetings and exhibits for the public. An increasing number of efforts of this kind have been made by professional scientific groups with marked success.

Almost all states now have Nutrition Committees organized to broaden nutritional knowledge. A number of local committees and councils have been formed, particularly in the larger urban areas. Some food technologists are active in the work of these organizations. But there must be general participation by all food scientists, technologists and other qualified professional persons, however, to make it possible to raise the total effort to the level required to reach all of our people to a reasonably satisfactory degree. By joining forces with workers in education, health and agriculture, food technologists can make a major contribution toward the achievement of an effective and integrated nutrition education program.

In contemplating the problem of broadening nutrition education, we must realize that the extension of knowledge that increases nutritional awareness is very difficult. To effect material improvement in the food habits of our people will require a sustained effort over a long period of time. The problem can be solved, however, if we are willing to help make possible the needed extra educational effort.

"OUR REAL GOAL IS A MORAL ONE"

The opportunity and the responsibility are ours to accept if we so decide. In this connection it seems quite pertinent to call attention to the views expressed by Dr. Lee A. DuBridge, President of the California

Institute of Technology, in speaking on the subject "The Aims of Science" at a recent meeting of the Nutrition Foundation. Dr. DuBridge pointed out the importance of keeping in mind the goals we seek as scientists and Americans. He suggested that these goals are not merely more food or more products, but that our real goal is a moral one—more happiness for us all as individuals, more opportunity for each person to seek happiness in his own way.

Emphasizing the matter of goals because the obvious is often forgotten, Dr. DuBridge said that we become so absorbed in our equipment, new food products, new medicines, that we tend to think of them as ends in themselves, forgetting their uses.

Today science and technology are being simultaneously praised and condemned, supported and attacked. Although scientists may be acclaimed as a group, as individuals they are accused of being materialists. From this, it appears that scientists have not told their story adequately. Dr. DuBridge urged scientists to throw off their reticence and announce their aims by saying, "We are working for the betterment and happiness of human beings—nothing less and nothing more."

Scientists would agree with this statement, and would have a question only as to how to say what their aims are in ways that would be readily understood and accepted by the public at large.

I would like to leave this thought with you. Technologists and scientists in the food field could not choose a more effective way to give practical, convincing expression to their aims and the aims of science than through enthusiastic participation in nutrition education activities that can contribute so importantly to the betterment and happiness of the entire population.

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Evaluation of Egg Color

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(Manuscript received May 27, 1955)

The depth of color of eggs and separated egg yolks may vary considerably from lot to lot. This is not surprising since the color, which is due primarily to the presence of pigments of the cartenoid group, is strongly influenced by the type of feed given to the chickens. Egg color is important to purchasers such as bakers and makers of macaroni products because of the color this ingredient imparts to the finished product. Thus, color is frequently an important factor in trading in eggs.

No single uniform method for evaluating egg color has yet been accepted by all producers, distributors and users. The N. E. P. A. method *(2)* is used by a large group, while the cereal chemists favor Dalby's *(2)* procedure. Others have developed methods for their own use which they are reluctant to discard even though they may conflict with methods used by other individuals and groups. Furthermore, no method has yet been advanced that would permit the use of a variety of different measuring instruments and still give similar or comparable results. The method suggested in this paper is an attempt to put the evaluation of egg color on a more rational and uniform basis without requiring new or special instruments.

All of the methods now in use are modifications of a method developed and reported by Turner and Conquest *(3)*. All modifications employ acetone for extracting the coloring matter from the sample and all determine the amount of color present by comparing the color of the acetone solution with that of standard potassium dichromate solutions. Most of the methods differ from each other in one or more of the following ways: (a) sample size, (b) amount of acetone used for extraction and (c) scale employed for evaluating the egg color.

Until quite recently, all of the methods employed visual comparison as a means of color evaluation. The methods of both Dalby *(1)* and Kahlenberg *(2)* apply instrumental procedures for measuring the color of the acetone extract. This was a definite progressive step since an instrumental reading removes much of the subjectivity of color reading. Both use potassium dichromate as the standard, but report the color differently. The former procedure *(1)*, now used by the American Association of Cereal Chemists, expressed the egg color as 25 times the number of milligrams of potassium dichromate equivalent to the color extracted from one gram of sample, irrespective of whether the sample was whole eggs, yolks, or dried eggs. In the latter procedure *(2)*, now used by the National Egg Producers Assoc., the egg color is expressed as grades

numbered 1 to 10. These numbers correspond to milligrams of potassium dichromate equivalent to the color extracted from one gram of whole eggs or the weight of yolks or dried whole eggs equivalent to 1 gram of whole eggs. This illustrates differences encountered in expressing egg color, and the following table shows a comparison of some of the existting methods for expressing egg color.

This table clearly illustrates the differences in grading systems. Comparison under present conditions cannot be accurate and only represents approximations.

TABLE 1
Comparison of some of the different methods for expressing egg color

N. E. P. A.	Producer A		Purchaser B	Producer C		Purchaser D		Cereal Chemists	
for both whole eggs and yolks	for whole eggs	for yolks	for both whole eggs and yolks	for whole eggs	for yolks	for whole eggs	for yolks	for whole eggs	for yolks
1	1	2	0.3			1	2	40	100
2	1.5	3.5	1.5	1	1.5	1.5	3.5	80	160
3	2.5	4.5	2.0		2.5	2.5	5.5	120	220
4	3.5	5.5	3.0	2.5	3.5	3.5	7.5	160	280
5	4.5	6.5	4.0		4.0	4.5	9.5	200	340
6	5.5	8.0	5.0	4.0	4.5	5.5		240	400

For more uniformity and better agreement in the evaluation of egg color, two steps appear necessary, (a) to express the color on the same basis and (b) to find a standard more closely related to egg pigments than potassium dichromate. The method of reporting color on the basis of one gram of sample, as is done in Dalby's method, appears to be better than that of selecting an arbitrary sample size for each type of sample in order to express color on the basis of whole eggs. Results reported in this paper, therefore, will all be on the basis of one gram of sample.

The need for a standard other than potassium dichromate is evidenced by the fact that even when using the same sample size and the same scoring system, the results found by the Cereal Chemists' method will not agree with those by the N. E. P. A. method. The former measures the color in the region of 455 millimicrons and the latter employs the region of 410 millimicrons. The different results are due to the fundamental differences in the color characteristics of egg pigments in solution and of potassium dichromate solution in the region of 400 to 470 mμ, as shown in Figure 1. The spectral transmittance curves show that egg color exhibits a maximum absorption of light in the region of 455 mμ which makes this region the one best suited for instrumental evaluation of that color and that potassium dichromate and egg pigments have markedly different characteristics in the region of 400 to 470 mμ. Variations that can occur when expressing color in terms of potassium dichromate at different wavelengths are shown in Table 2, which is the result of a series of measurements made on acetone solutions of egg pigments with a Coleman Model 6-A spectrophotometer at selected wavelengths and with a Cenco-Sheard-Sanford Photelometer using the blue filter (maximum transmittance at about 410 mμ).

These data show: (a) The marked variation in values for egg color when measured at different wavelengths

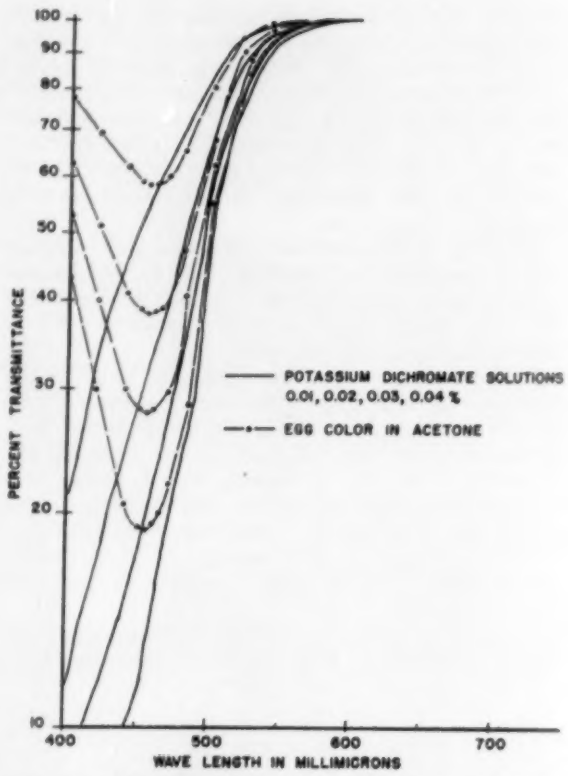

Figure 1. Spectral transmittance curves for potassium dichromate solutions and acetone solutions of egg color.

and expressed in terms of potassium dichromate, (b) the effect of differences in instrument characteristics, as shown in measurements with the Photelometer and spectrophotometer at 410 mμ; and (c) the lack of concordancy between Photelometer results and spectrophotometer results at 455 mμ, the region best suited for measuring egg color.

The authors propose to overcome these variations and difficulties by using pure carotene as a standard substance and by reporting egg color in terms of carotene. The spectral transmittance curves of carotene are

TABLE 2
Egg color expressed as milligrams of potassium dichromate equivalent to color from one gram of sample

Sample	Color measured with				
	C-S-S Photelometer	Coleman Model 6-A Spectrophotometer at—			
		410 mμ	435 mμ	455 mμ	470 mμ
A	0.7	0.2	0.8	1.1	1.3
B	0.8	0.2	0.9	1.2	1.4
C	1.4	0.8	1.6	2.3	2.7
D	2.1	1.1	2.3	3.2	3.7
E	4.3	3.1	4.6	6.0	8.5
F	8.1	6.2	8.8	11.6	15.2

almost identical with those of egg color, Figure 2. Thus, it should be possible to measure egg color in the region of 455 mμ with different instruments and obtain practically the same results. This was found to be true (See Table 3).

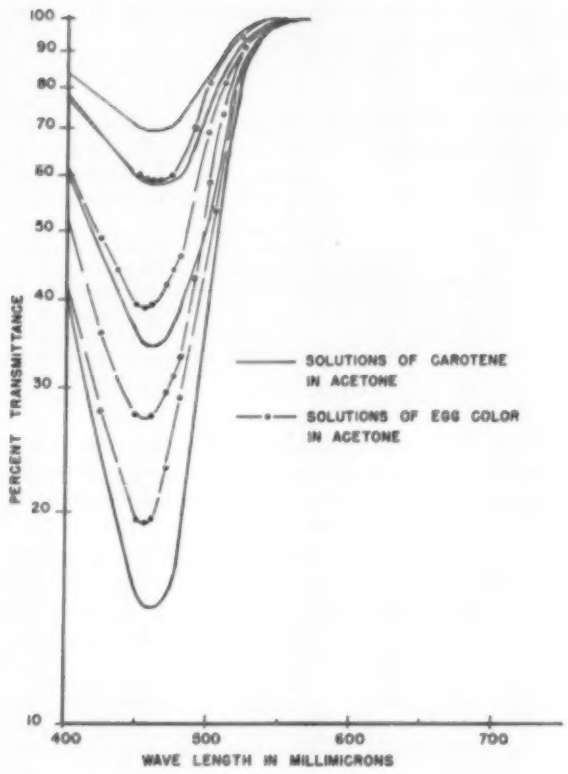

Figure 2. Spectral transmittance curves for acetone solutions of egg color and carotene.

These data show: (a) None of the marked variation encountered with potassium dichromate; (b) that the measurements made on a filterphotometer agree well with those on a spectrophotometer at 455 mμ, the region best suited for measuring egg color; and (c) differences in instrument characteristics have little effect on the results.

TABLE 3
Egg color expressed as micrograms of carotene equivalent to color from one gram of sample

Sample	Color measurements with				
	C-S-S Photelometer and blue filter	Coleman Model 6-A at—			
		410 mμ	435 mμ	455 mμ	470 mμ
A	7	8	7	7	7
B	8	8	8	8	7
C	15	16	15	14	14
D	20	22	21	20	19
E	34	36	36	32	31
F	63	71	70	64	58

A further comparison of data obtained using two instruments is given in Table 4. The samples ranged from light to dark in color.

These data show that comparable results can be obtained with different instruments over the range of light to dark eggs when carotene is used as the standard and egg color is expressed in terms of carotene.

Since carotene solutions are unstable, they are not suitable for regular checking of an instrument. This disadvantage does not rule out the use of carotene as a standard. If the transmittances of selected potassium dichromate solutions are measured at the same time that the instrument is calibrated with carotene solutions, the selected potassium dichromate solution (transmittance 20% to 80%) can be used to check the constancy of the instrument when required.

TABLE 4
Egg color determined on different instruments using carotene as a standard

Sample	Micrograms of carotene per 100 ml. of acetone soln. using		Micrograms of carotene per gram of sample [1] using	
	C-S-S Photelometer and blue filter	Spectrophotometer Coleman Model 6A, Wavelength 455 mμ	C-S-S Photelometer and blue filter	Spectrophotometer Coleman Model 6A, Wavelength 455 mμ
1. Yolk	40	45	16	18
2. Whole Eggs	55	54	11	11
3. Whole Eggs	62	55	12	11
4. Yolks	86	85	34	34
5. Whole Eggs	86	92	17	18
6. Yolks	90	88	36	35
7. Whole Eggs	111	119	22	24
8. Yolks	118	119	47	48
9. Whole Eggs	170	158	34	32
10. Yolks	168	158	67	63
11. Yolks	232	240	93	96
12. Whole Eggs	315	320	63	64

[1] Micrograms per gram of sample is numerically the same as parts per million.

Visual methods might be expressed in terms of carotene when the relationship between the carotene and potassium dichromate solutions are established visually. These, however, cannot be as accurate as instrument procedures and are always subject to the personal factors which may vary from day to day with a given operator and from operator to operator.

METHOD

Reagents:

1. Acetone, C. P. grade.
2. Potassium dichromate, reagent grade.
3. Carotene (90% beta-10% alpha). This can be obtained from General Biochemicals, Inc., Chagrin Falls, Ohio. A calibration graph should be prepared as soon as possible after a fresh supply of carotene is received. Carotene is unstable, but it can be kept for several months without significant change if stored in sealed tubes and kept in a refrigerator.
4. Carbon tetrachloride, reagent grade.

Standard Color Solutions:

1. Carotene solutions. These solutions must be prepared the same day the instrument is calibrated and in their preparation, carotene from a freshly opened tube must be used.

   (a) Standard Carotene Solution:

   Weigh exactly 0.0500 g. of carotene into a 150-ml. beaker. Add 5 ml. of carbon tetrachloride and stir with a glass rod to dissolve the carotene. Add ca 70 ml. of acetone, stir, allow to stand 1 or 2 minutes and decant the solution into a 500-ml. volumetric flask, retaining any undissolved carotene in the beaker. Treat any undissolved

carotene as before and repeat until carotene is completely dissolved and transferred to the volumetric flask. Dilute to mark with acetone and mix thoroughly. One ml. of this soln. contains 100 micrograms of carotene.

(b) Diluted Carotene Solutions:

Pipet 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 ml. of the Standard Carotene soln. into a series of 100-ml. volumetric flasks. Dilute to mark with acetone and mix thoroughly. The diluted solns. contain 50, 100, 200, 300, 400, and 500 micrograms of carotene per 100 ml. of soln.

2. Standard Potassium Dichromate Solutions:

(a) Weigh the specified amount of potassium dichromate to the nearest milligram and transfer quantitatively to 1-liter volumetric flasks.

Amount to weigh, g.	Concentration of soln., %
0.100	0.01
0.200	0.02
0.300	0.03
0.400	0.04
0.500	0.05

Dissolve in ca. 500-ml. of distilled water, dilute to mark and mix thoroughly.

Calibration:

1. Measure transmittance of the diluted carotene solns. at 455 mμ with spectrophotometer or filter photometer set to read 0% transmittance when no light reaches the photocell and 100% when an absorption cell is filled with acetone.

   The instrument may be calibrated using measurements anywhere in the region 400 to 470 mμ if it is not possible to make them at 455 mμ. However, the samples must be measured under exactly the same conditions as those used for calibration.

2. Plot on semi-logarithmic paper the transmittance for each soln. (on the logarithmic scale) against the micrograms of carotene in 100 ml. of soln. Draw a smooth curve from 100% transmittance through the points. Do not use or plot transmittance values below 10%.

3. Measure the transmittance of each of potassium dichromate solns. at the same time and under exactly the same conditions.

4. Record the transmittance values of potassium dichromate solns. Select solns. with transmittance values between 20 and 80% for routine checking of the instrument.

Checking Instrument:

1. Measure the transmittance of one or more of the selected potassium dichromate solns. each day tests are made. The instrument is in proper adjustment as long as these measurements check those made at the time of calibration within the limits established for the instrument. When measurements made on the dichromate solution are outside acceptable limits, repeat calibration using carotene and potassium dichromate solutions.

Procedure:

1. Weigh an appropriate sample into a 150-ml. beaker. The transmittance of the resulting soln. should be between 15 and 90% transmittance. Suggested sample size and ml. of acetone to be used are given below:

Sample	Grams	Acetone, ml.
Frozen or liquid whole eggs	5.0	95.0
Frozen, liquid, salted or sugared yolks	2.5	97.5
Dried Whole Eggs or Yolks	1.25	99.0

2. Measure the specified amount of acetone into a clean graduated cylinder.

   Note: Graduated cylinder must be free from water when measuring acetone. After washing with water, dry or rinse twice with acetone before using to measure acetone for the test.

3. Add approximately 2.5 ml. of acetone; break up lumps of sample with a stirring rod and stir until thoroughly mixed and smooth. Larger quantities of acetone at this point will cause hard lumps and make extraction of pigments more difficult.

4. Add the remainder of measured acetone and continue stirring until the pigment in the sample has been entirely extracted. One minute has been found sufficient.

5. Place a folded filter paper, Whatman No. 4 or equivalent, in the top of a 50-ml. beaker and filter the acetone soln. into this beaker.

6. Transfer a suitable portion of the clear filtrate to the same type of clean and dry absorption tube as that used for calibrating the instrument and measure the transmittance.

7. Record the transmittance value and read the carotene content of the soln. from the concentration-transmittance calibration graph.

Calculations:

Color, in micrograms of carotene per gram of sample, =

$$\frac{\text{micrograms of carotene, per 100 ml. soln.}}{\text{weight of sample, grams}}$$

SUMMARY

A method has been proposed for evaluating egg color in terms of carotene rather than of potassium dichromate. By this method the same results can be obtained with different instruments when the color is measured at any selected point in the region of 455 mμ and the results expressed on a sample weight basis.

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The Physical and Functional Properties of Lyophilized Whole Egg, Yolk, and White[a, b]

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In a study of the effects of lyophilization on egg albumen, yolk, and whole egg as determined by standardized tests, it is shown that lyophilization had no detrimental effect on the functional properties of albumen (angel cake volume test) but impaired the emulsifying properties of yolk (mayonnaise stability test) and the properties of whole egg (sponge cake volume test).

Production of dried egg products increased greatly during World War II. Dried whole egg, white, and yolk offered many advantages. They were concentrated foods of high nutritive value, required relatively small shipping space, were fairly stable under Armed Forces field conditions, and lent themselves to many different food uses. After the war, the production of dried egg products declined greatly because of reduced needs by the Armed Forces and the lend-lease countries.

The increase during the last few years in the consumption of prepared mixes, especially mixes for angel cakes, has resulted in a strong new demand for dried egg products. The demand would be even greater if bakers, candy, mayonnaise, and ice cream manufacturers—who in many instances prefer dried to frozen or fresh egg products—could obtain equally good results with the dry product. During and since the war, research on dried egg products has resulted, it is true, in longer shelf life and better functional properties, but further improvements are possible and needed, as pointed out by Carlin *(6)* and Joslin and Proctor *(8)*.

Drying by lyophilization (freeze drying) was used on a large scale during the war to preserve blood plasma in its normal or near normal state for Armed Forces field use. This drying process is used for preparing a number of biologicals. Its use in the commercial drying of foods has been limited, however, because of the expensive equipment required *(7)*. Very little data *(3, 8, 10, 11)* dealing with the lyophilization of egg products and the effect on the functional properties of the product have been found in the literature.

This study was undertaken to provide more data on the effects of lyophilization on the physical and functional properties of egg products. Fresh, frozen, lyophilized and commercially spray dried samples of albumen, whole egg and yolk were compared.

EXPERIMENTAL PROCEDURES

The eggs used for the fresh, frozen, and lyophilized samples were randomly selected from the production of the University flocks. The spray-dried samples were obtained from a commercial company. The fresh samples were selected one to two days prior to use. The frozen and lyophilized products were prepared from pooled samples of blended material. Some of these samples were enzyme[c] treated to remove the naturally occurring glucose while others received no treatment. The frozen samples were stored at approximately −10° F. (−23° C.) and the lyophilized at approximately 55° F. (13° C.) for about 4 months until tested. The spray-dried samples were stored under the same conditions as the lyophilized.

Glucose removal. Removal of glucose from egg products before drying is a recent research finding. It effects longer shelf life and improves the functional properties of the products *(5, 10)*. The method employed was a modification of the enzyme method used by Scott *(13)* and covered by U. S. Patent 2,651,592. The liquid egg product was blended in a Waring blender operated at reduced speed for one minute in the case of albumen, 2 minutes for whole egg, and 4 minutes for yolk. During the blending a 125 ml. Erlenmeyer flask was submerged about one-half inch in the material to reduce the incorporation of air. The pH of the albumen was adjusted to 7.0 to 7.5 with citric acid. No adjustment was made in the pH of the whole egg and yolk. The enzyme preparation, mixed to a slurry with a little egg, was added at the level of 0.055 g. of enzyme per 500 g. of albumen. The enzyme contained 1,500 glucose oxidase units per gram. (A unit is the quantity of enzyme required to cause an oxygen uptake of 10 cu. mm. per minute under the following conditions: Solution: 3.3% Cerelase, 0.4% sodium salt of dehydroacetic acid, m/10 phosphate buffer, pH 5.9, temperature, 30° C.) The egg product was stirred gently and continuously for a 7-hour period in the water bath. Hydrogen was added at 15-minute intervals, using 2 ml. of 35% hydrogen peroxide, diluted four fold, per 500 g. of egg white. The conversion of glucose to gluconic acid was followed by Kline's *(10)* modification of the Somogyi analytical method for reducing sugar. In the case of whole egg and yolk, 0.3 g. of enzyme was used per 900 g. of egg product. The reaction time was 3.5 hours.

Lyophilization. The laboratory apparatus used to prepare the lyophilized samples is shown in Figure 1. The material to be dried was frozen to the inner surface of the balloon type 3000 ml. flasks by hand rotation in an acetone bath chilled with dry ice. The bath was maintained at approx. −20° F. (−29° C.). It was found that much lower temperatures caused the partially frozen material to crack, thereby breaking contact with the glass surface. This reduced the heat transfer efficiency, causing a prolonged drying time. The flasks were then connected to the vacuum system. The flask ground glass connections were 1⅝ in. in diameter. The T tube extended into a metal condensing chamber 12 in. deep and 4½ in. in diameter. The chamber was chilled by a bath containing acetone and dry ice, to a temperature below −60° C. (−76° F.). A residual pressure of less than 500 microns was maintained during the drying process; this was measured with a Stokes McLeod high vacuum gauge. The vacuum was obtained with a Cenco Hypervac No. 4 high vacuum pump.

Some of the samples were prepared in a Stokes Model 2004 freeze-drying unit in pyrex trays (Figure 2).

After drying, the lyophilized material was removed from the flasks and forced through a 20-mesh screen to break up the friable sponge-like structure.

Moisture determination was made on approximately two

[a] This study was supported in part by a grant from the Ballas Egg Products Corporation, New York 13, N. Y., to The Ohio State University Development Fund.

[b] Presented before the Fifteenth Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 15, 1955.

[c] Glucose-oxidase and catalase preparation supplied by Takamine Laboratory Inc., Clifton, New Jersey.

Figure 1. Laboratory lyophilization apparatus showing: freezing and drying flasks; condensing chamber surrounded by acetone dry ice mixture in insulated can; vacuum gauge; and vacuum pump.

gram samples in a vacuum drying oven at 25 inch vacuum and 212° F. (100° C.) for 7 hours.

pH determination was made on reconstituted samples containing one part powder to three parts distilled water.

Solubility index was determined according to the method of Bishov and Mitchell *(2)*.

Angel cake test. The final criterion for evaluating the albumen functional properties was angel cake volume. Other tests included are beating time of the meringue and specific gravities of the meringue and batter. A modification of the Slosberg *(14)* method was used. The formula contained: egg white, 61 g.; sugar, 62.5 g.; cream of tartar, 0.9 g.; salt, 0.3 g.; and flour, 22.5 g. The temperature of the egg white was brought to 21° C. (70° F.) in a Hobart Electric Mixer bowl (Model 3-B) and the beating started at speed 10. The beating was stopped at the end of 3 seconds and the cream of tartar and salt added. Forty-seven grams of sugar were added in 4 equal portions at the end of 6, 9, 12, and 15 seconds. The mixture was then beaten to a "finish," and the beating time of the meringue recorded. The flour-sugar mixture (22.5 g. flour and 15.5 g. sugar), sifted together three times, was folded into the meringue in three equal portions (10 strokes of a French ballon whip used for each addition). The specific gravities of the meringue and batter were determined. Ninety grams of batter were weighed into a tared rectangular baking pan (5½ by 3 by 2 in.) fitted with wax paper in the bottom and baked at 350° F. for 27 minutes. The cake volume was determined by the seed displacement method.

Mayonnaise test. The criterion for evaluating the yolk samples was its emulsifying properties in producing a stable mayonnaise. The formula and method reported by Miller and Winter *(12)* was followed with the following modification; the samples were stored at 40° F. (4° C.) for 48 hours. A portion of the sample was weighed in a 50-ml. centrifuge tube and centrifuged for 15 minutes at 2,000 r.p.m. in an International centrifuge Model 2 v. In the first trial, the percent oil separation was determined volumetrically. In subsequent trials it was determined on a weight basis.

Sponge cake test. The whole egg samples were evaluated by their performance in sponge cakes. The method and formula reported by Kline *et al. (9)* was followed except that vanilla was omitted and a 100-g. portion of the batter was weighed into a tared rectangular baking pan (6½ x 2¾ x 2¼ in.).

RESULTS AND DISCUSSION

Albumen. The moisture, pH and solubility index of the lyophilized and spray dried samples have been summarized in Table 1.

The moisture content of 5 lyophilized albumen samples ranged from 4.0 to 6.3% with an average of 4.9; that of five commercial spray dried samples ranged from 6.0 to 8.5% with an average of 7.1.

The pH range of 4 lyophilized enzyme treated albumen samples ranged from 8.2 to 8.9; that of one untreated sample was 9.6. The pH of the commercial spray-dried samples ranged from 7.5 to 7.8.

The solubility index of 4 lyophilized enzyme-treated albumen samples ranged from 1.3 to 1.5, whereas that of one untreated sample was 1.6. The solubility index of 5 commercial spray-dried samples ranged from 1.4 to 1.6. There was no appreciable difference in solubility index of the spray-dried and lyophilized albumen samples.

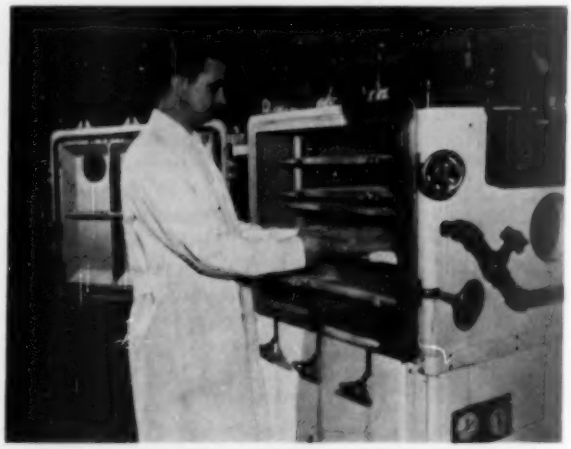

Figure 2. Stokes freeze drying apparatus—egg products frozen and dried in shallow pyrex trays.

Data for angel cakes made from various types of egg albumen are summarized in Table 2.

The spray-dried albumen showed an increased beating time, and the cake volume was slightly less than that of the other samples.

Since the frozen and lyophilized samples were from the same pooled material, it is evident that lyophilization had no detrimental effect on the performance of albumen in making angel cakes.

TABLE 1

Moisture, pH and solubility index of dried egg products

	Albumen			Whole Egg			Yolk		
	Moisture	pH	Solubility	Moisture	pH	Solubility	Moisture	pH	Solubility
Lyophilized (enzyme)	4.8	8.6	1.4	3.4	7.2	1.2	1.5	6.9	0.5
Lyophilized (untreated)	5.8[1]	9.6[1]	1.6[1]	2.4	7.8	1.2	2.1	7.0	0.6
Spray Dried	7.9	7.5	1.5	4.8	7.2	1.2	4.3	6.8	0.7

[1] Not used in albumen summary.

TABLE 2
Effect of various types of albumen on angel cake volume

	Beating time of meringue	Specific gravity of meringue	Specific gravity of batter	Angel cake volume per 90 g. batter
	(seconds)			(ML)
Fresh	23	.17	.28	471
Frozen	30	.18	.28	476
Lyophilized (enzyme treated)	30	.19	.30	490
Spray dried	45	.20	.32	459

Yolk. The moisture content of 5 lyophilized yolk samples ranged from 1.4 to 2.7% while that of 4 commercial spray-dried samples ranged from 2.7 to 4.3%.

The pH of the lyophilized yolk samples ranged from 6.9 to 7.0; that of the commercial spray-dried samples ranged from 6.8 to 7.2.

The solubility index of 4 lyophilized yolk samples ranged from 0.3 to 0.5. The solubility index of a single lyophilized sample, which had been diluted with an equal volume of water before drying, was 0.7.

The lyophilized yolk, after being forced through a 20-mesh screen, appeared to be a granular material of undesirable particle size. Since lyophilized material occupies approximately the same volume as the liquid material *(7)*, the dilution of the yolk before lyophilization increased the volume of the dry material resulting in a product with a more desirable particle size after screening.

The solubility index of 4 commercial spray-dried samples ranged from 0.4 to 0.7.

Data for mayonnaise stability made from various types of yolk have been summarized in Table 3. It is

TABLE 3
Effect of various types of yolk on mayonnaise stability

	% Oil Separation
Fresh	1.2
Frozen	3.0
Lyophilized	4.6
Lyophilized (dilute)	2.9
Spray dried	8.8

evident that drying of yolk impairs its emulsifying properties in producing a stable mayonnaise when compared to the fresh samples. These data indicate that the extent of impairment is more severe in spray drying than in lyophilization. Dilution of the yolk material before lyophilization improved its emulsifying properties.

Whole egg. The moisture content of 5 lyophilized whole egg samples ranged from 2.2 to 3.4%; that of 3 commercial spray-dried samples varied from 2.4 to 4.8%.

The pH of the lyophilized samples varied from 7.0 to 7.8, and the commercial samples from 6.7 to 7.2. The solubility index of the lyophilized samples ranged from 1.2 to 1.3 and the commercial spray-dried samples from 0.9 to 1.3.

Whole egg. Data for sponge cakes made from various types of whole egg products are summarized in Table 4.

A relationship between the specific gravity of the batter and cake volume is indicated. As the specific gravity of the batter increased, cake volume decreased. The lyophilized and spray-dried whole egg samples show a decreased cake volume when compared to the fresh and frozen samples (Fig. 3). Joslin *(8)* attributed the loss of foam volume in reconstituted whole egg powders to the breakdown of the natural fat emulsion of the fresh eggs.

TABLE 4
Effect of various types of whole egg on sponge cake volume

	Specific gravity of foam	Specific gravity of batter	Sponge cake volume ml./ 100 g. batter
Fresh	.27	.37	639
Frozen	.26	.38	598
Lyophilized (enzyme treated)	.36	.46	473
Lyophilized (untreated)	.36	.48	440
Spray dried (enzyme treated)	.77	.80	292

Although there is a great difference between the lyophilized and spray-dried samples in sponge cake volume, the difference may not be as great as indicated because the samples were not from the same source.

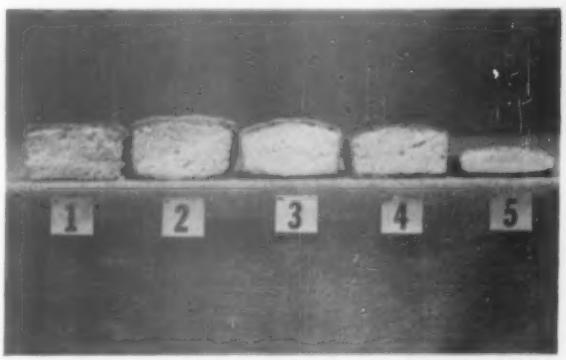

Figure 3. Sponge Cake volume. 1: frozen; 2: fresh; 3: lyophilized, enzyme treated; 4: lyophilized; 5: spray dried.

It appears that the impairment to the whipping characteristics of reconstituted whole egg powders is more severe in spray drying than in lyophilization. Carlin *(6)* reported the whipping ability of both yolks and whole egg is greatly diminished by spray drying.

SUMMARY

Under the conditions employed in these investigations, lyophilization of egg albumen had no detrimental effect on its functional properties as measured by angel cake volume.

Lyophilization of yolk impaired its emulsifying properties as measured by mayonnaise stability. The impairment was less in yolk diluted before freeze-drying.

Lyophilization of whole egg impaired its functional properties as measured by sponge cake volume.

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A Single-Sample Method for Foreign Flavor Detection

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A method for foreign flavor detection is described that involves tasting single samples of treated and untreated material presented at random over adequately spaced intervals. Off-flavors were detected by this method in apples sprayed with demeton and in apple juice prepared from demeton-sprayed apples. Results of taste tests on the apple juice samples by the triangle difference method were inconclusive.

The perennial problem of foreign flavors in food products has been intensified by the recent introduction of new organic insecticides. Some of these materials produce a pronounced, unpleasant flavor in crops to which they are applied, while others may cause only slight off-flavors which may also be less objectionable in quality. Losses experienced by food handling and processing concerns have stimulated studies on the effect of agricultural chemicals on the flavor of crops to which they are applied.

This report describes a single-sample taste method developed in an effort to overcome certain difficulties encountered when the triangle difference method was applied, and the two methods are compared. Most important among these difficulties were: (a) preparation of treated and untreated materials that differed only in the possible presence of an off-flavor in the treated material, (b) perception of the off-flavor as an unpleasant aftertaste that was not detected until several samples had been tasted, and (c) persistence of off-flavor so that the tasters were confused in making later tastes. The single-sample method appears to reduce the severity of these problems by avoiding direct comparison between treated and untreated samples.

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The method is based on the assumption that a foreign flavor is of no consequence if tasters, selected for acuity with the material under test, cannot detect it when making a series of single, adequately spaced tastes in which treated and untreated samples are presented at random. While such a method would appear to be less sensitive than direct-comparison methods it actually was found to be more sensitive for the material under test in this study. In common with other sensory taste panel methods used in laboratories it is not designed for determining consumer acceptance, or resistance to foreign flavors that may be detected.

EXPERIMENTAL PROCEDURE

Preparation of samples. Taste-panel tests were conducted on apple juice prepared during the 1952 and 1953 seasons and on fresh apples grown during the 1953 season. The apples were from experimental plots of the Tree Fruit Experiment Station, Wenatchee, Washington. Table 1 presents data on the spray treatments for each plot.

Representative, field-run Golden Delicious were harvested at prime maturity for fresh market or storage from each experimental plot and carefully composited for preparation of juice. In 1952 one two-box lot from each treatment was pressed the day after harvest and another after the fruit had been ripened at room temperature for 2 weeks. Three lots of juice were prepared from replicate two-box lots of control fruit on the day after harvest and three more lots were prepared after 2 weeks' ripening at room temperature. A single lot of juice was also prepared from control fruit that had been ripened one week to provide additional variation in untreated samples for use in the simple-sample method. Golden Delicious apples used for the 1953 study consisted of one two-box lot from each treatment and duplicate two-box lots from control fruit. All lots were permitted to ripen one week between harvest and pressing.

Each two-box lot, about 70 pounds, was ground in a grater-type mill and pressed in a hydraulic press equipped with nylon cloths and aluminum racks. Each replicate of the control treatments was handled as a separate lot. The juice was treated with sufficient pectin-decomposing enzyme preparation to obtain

TABLE 1

Spray treatments given apple plots (Treatment per 100 gallons spray)

Plot No.	Pre-Bloom	Date	1st cover	Date	2nd cover	Date	3rd cover	Date
			1952					
2	demeton,[1] 1 pt. 32%	4/27	none		demeton, 1 pt. 50%	6/23	demeton, 1 pt. 50%	8/12
5	none		demeton, ½ pt. 50%	5/23	demeton, ½ pt. 50%	6/24	none	
7	none		parathion, 1 lb.	5/23	parathion, 1 lb.	6/24	none	
			1953					
2	demeton, 1 pt. 42%	4/21	demeton, 1 pt. 42% DDT, 2 lb.	5/18	demeton, 1 pt. 42% DDT, 1½ lb.	6/24	demeton, 2 pts. 21%	7/27
3	none		none		none		none	
6	parathion, 1 lb.	4/10	none		none		none	
7	none		demeton, ¼ pt. 42% DDT, 2 lb.	5/15	demeton, ¼ pt. 42% DDT, 2½ lb.	6/24	demeton, ½ pt. 21%	7/24
8	none		demeton, 1 pt. 42% DDT, 2 lb.	5/18	demeton, 1 pt. 42% DDT, 2 lb.	6/24	demeton, 2 pts. 21%	7/26

[1] 0-0-diethyl 0-2-(ethylmercapto)-ethyl thiophosphate.

clarification at room temperature within 18 hours. After clarification the juice was filtered through cloth with diatomaceous filter aid, flash pasteurized at 190° F., filled into 12-ounce special-enamel cans, sealed, inverted, and then water cooled. The canned juice was stored at 32° F. for 2 to 6 months until used for flavor-evaluation studies.

Fresh apples used for taste tests were Starking Delicious and Winesap varieties. The fruit was harvested and stored for about 7 months before the taste test was made.[b]

Triangle taste method. The triangle taste test *(2)* was made with a panel of 20 tasters all of whom had had considerable experience in tasting apple juice. Fourteen to 18 participated in each test. Three 50-ml. portions of juice, two of which were identical and the third different, were presented in coded beakers. The position of the odd sample with respect to the pair was randomized. The samples were presented in subdued, red light to prevent possible detection of the odd sample by appearance.

The tasters were informed that the study was being made to determine whether or not foreign flavor was present. They were instructed to select the odd sample and were asked to indicate whether the selection was made on the basis of aroma, apple flavor, sweetness, tartness, or astringency. They were also asked to indicate if they detected a flavor that was foreign to apple juice and the sample or samples in which it occurred. Selection of an odd sample was required, even if it involved guessing, but indication of basis of selection or presence of foreign flavor was not.

Single-sample taste method. The tasters were presented only one sample at each test and were given as much as they cared to consume. At least 3-hour intervals occurred between tests. The tasters were informed that the test was being made to determine whether a foreign flavor was present in samples receiving certain spray treatments. No attempt was made to acquaint them with the type of off-flavor being studied though several were familiar with the material in the form of an insecticide. They were informed that samples receiving these treatments would be presented at random with untreated samples. They were asked to indicate whether or not they detected a flavor foreign to apples, or apple juice, in each sample as it was presented. In tests made on the 1953 samples, if a foreign flavor was detected the taster was asked to indicate whether it was strong, moderate, or a trace, and whether it was considered acceptable, objectionable, or highly objectionable. They were also asked to describe the flavor, if possible.

It was emphasized that this test did not involve guessing, as might be the case in selecting the odd sample in the triangle difference test. A sample either did or did not have a foreign flavor to the taster and a foreign flavor should be indicated only if positively detected. To reduce the influence of external psychological factors, tasters were not given results of their own or other tasters until the entire test had been completed, and they were asked not to discuss their opinions with other tasters.

[b] Harvest, sample, selection, and storage were conducted by Fisk Gerhardt, U. S. Department of Agriculture, Agricultural Marketing Service, Wenatchee, Washington.

The data were analyzed by the chi-square analysis of a 2×2 block *(12)*, using Yates's correction for continuity.

RESULTS AND DISCUSSION

Results of the triangle difference tests for juices prepared in 1952 and 1953 (Table 2) are inconclusive in demonstrating the presence or absence of foreign flavor. In only one of the tests made in 1952 was there a significant difference between the treated and the control samples, which was balanced by 3 tests in which significant differences were detected between control samples. In the 1953 study a significant difference was obtained in only one test. The samples in this test were so nearly identical that 4 of the 10 judges with correct scores indicated that they had guessed. These results illustrate the difficulty in preparing treated and untreated materials that differ only in possible foreign flavor in the treated samples. Although particularly serious in apple juice studies where processing opera-

TABLE 2

Triangle difference taste tests on apple juice (1952-1953)

Sample description			Ratio correct judgments to total judgments	No. of foreign flavor [3] comments of correct judgment		Total foreign flavor comments
Plot No.[1]	Treatment [1]	Post-harvest ripening [2]		Treated	Control	
			1952			
2	demeton 1 pt.	1 day	20/33 [4]	5	1	8
2	demeton 1 pt.	2 weeks	16/34	5	1	8
5	demeton ½ pt.	1 day	14/30	1	1	2
5	demeton ½ pt.	2 weeks	8/30	1	1	10
7	control 1 & 2	1 day	12/31	0	0	2
7	control 1 & 2	2 weeks	17/32 [5]	2	1	6
7	control 1 & 3	1 day	17/33 [5]	1	1	3
7	control 1 & 3	2 weeks	20/34 [4]	6	1	9
7	control 2 & 3	1 day	8/32	0	2	2
7	control 2 & 3	2 weeks	13/32	0	1	3
			1953			
6	control 1 & 2	1 week	5/14	0	1	3
7	demeton ¼ pt. (control—2)	1 week	4/16	0	0	3
7	demeton ¼ pt. (control—1)	1 week	7/17	0	0	3
8	demeton 1 pt. (control—1)	1 week	10/14 [4]	..	..	3
8	demeton 1 pt. (control—2)	1 week	6/16	4	0	5
7 & 8	demeton ¼ pt. demeton 1 pt.	1 week	6/15	2 (max.)	0 (min.)	7

[1] Detailed spray program given in Table 1.
[2] Time between harvest and pressing.
[3] Where both samples were controls, they are given in numerical order.
[4] Indicates significance at 0.01 level.
[5] Indicates significance at 0.05 level.

tions tend to introduce detectable flavor variations, the problem has also been reported by Hard and Ross *(7)* for other fruit.

Tasters' comments on foreign flavor, which constitute a modification of the triangle difference method, were likewise inconclusive in these tests. There appeared to be a concentration of foreign-flavor comments in tests involving treated samples in 1952, especially at the high treatment level. These comments were balanced, however, by numerous foreign-flavor comments when only untreated samples were compared. The foreign-flavor comments in the 1953 study were likewise inconclusive.

A noteworthy feature of these tests was the dissatisfaction of certain tasters with the method. Some insisted that certain samples had a disagreeable foreign flavor and these tasters often failed to identify the odd sample. One taster, who had demonstrated his ability to consistently detect demeton-induced flavor in a previous single-sample test, failed to identify the odd sample in three out of four triangle tests. Delay in the appearance of the off-flavor and its persistence after tasting were considered to account for the inability of these sensitive tasters to identify the odd samples. For this reason the single-sample method was investigated.

For convenience, data from the single sample tests have been segregated by treatments, and the tasters by judgments. The order in which the samples were presented can be ascertained from the data in the "date of test" column.

Five tasters who insisted they detected foreign flavors in the 1952 triangle test were selected for the 1952 single-sample test (Table 3). A sixth taster, C, who had not previously participated in apple-juice tests, was included because he had had experience with the spray material used and felt sure he could taste it, if it were present. This individual tasted the first sample in the table first and the sixth sample second, which was the reverse order from that of the other tasters. Only in this first sample did he indicate a foreign flavor in a control. The fact that it was the first sample tasted and consisted of relatively poor quality juice from unripened apples *(9)* may account for the wrong judgment.

Results showed that three of the six tasters, A, B, and C, could detect a foreign flavor in the treated samples. Tasters A and C considered the off-flavor objectionable while B considered it acceptable. Tasters D and E were

TABLE 3

Single sample taste test on apple juice—1952 (+ indicates foreign flavor, — indicates no foreign flavor)

Plot [1] No.	Treatment [1]	Post-harvest ripening	Date of test	Tasters					
				A	B	C	D	E	F
7	control	1 week	12/22/52 p.m.	—	—	+[2]	—	—	—
7	control	1 day	12/23/52 a.m.	—	—	—	+	+	+
7	control	2 weeks	12/30/52 a.m.	—	—	—	—	—	—
7	control	1 week	1/2/53 a.m.	—	—	—	—	—	+
3	demeton 1 pt.	1 day	12/23/52 p.m.	+	+	+	+	+	+
3	demeton 1 pt.	2 weeks	12/22/52 a.m.	+	+	+[2]	—	—	+
5	demeton ½ pt.	1 day	12/31/52 a.m.	—	+	+	—	—	+
5	demeton ½ pt.	2 weeks	12/29/52 p.m.	+	+	+	—	—	+

[1] Detailed spray program shown in Table 1.
[2] Taster C tasted these samples in reverse order.

apparently unable to detect the off-flavor. Taster F found a foreign flavor in all of the treated samples but also indicated a foreign flavor in two of the controls. These tasters also apparently confused the poor flavor of juice from unripened apples with foreign flavor. Although a conclusion of foreign flavor may be perfectly justified in such samples, the flavor being scored as foreign is known not to be due to the treatment under study. Statistical analysis of the data from all tasters shows detection of foreign flavor to be significant at the 1% level.

In the single-sample test on apple juice in 1953 (Table 4), all members of a panel routinely tasting apple juice on variety and other studies in this laboratory were used. The results are divided into three groups of tasters. One group, A through F, consistently gave a negative reaction to all untreated samples but indicated a foreign flavor at least once when treated samples were presented. The second group, G through L, did not detect a foreign flavor in any of the samples, while the third group detected a foreign flavor in both treated and untreated samples. The tasters usually considered the foreign flavor objectionable unless only a trace was detected. It was variously described as skunk-flavor, soapy, metallic, bitter, or greasy. Some complained of a lingering after-taste while others found it a fleeting sensation. Statistical analysis of data from all of the tasters in this test showed the detection of a foreign flavor to be significant at the 1% level.

Differences in sensitivity among individuals to certain flavors, including those induced by some insecticides, is generally recognized *(3, 6, 10, 12)*. If the re-

TABLE 4

Single sample taste test on apple juice—1953. (+ indicates foreign flavor, +* indicates trace foreign flavor only, — indicates no foreign flavor. All apples ripened 1 week before pressing.)

Plot No.[1]	Treatment [1]	Date of test (1954)	Tasters																	
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R[2]
6	control—1	2/8 a.m.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	+*
6	control—2	2/9 p.m.	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+*	—	—	+*
6	control—1	2/10 p.m.	—	—	—	—	—	—	—	—	—	—	—	—	+*	—		+	+*	—
6	control—2	2/12 a.m.			—	—	—	—	—	—	—	—	—	—	—	—		—	+*	—
7	demeton, ¼ pt. 42%	2/9 a.m.	+*	+	+	—	—	—	—	—	—	—	—	—	—	—	+	—		+
7	demeton, ¼ pt. 42%	2/10 a.m.	+	+*	+*	+*	+	—	—	—	—	—	—	—	+*	+*		—	—	+*
7	demeton, ¼ pt. 42%	2/11 p.m.	+	—	+*	+*	+	—	—	—	—	—	—		—	—		+*		+
8	demeton, 1 pt. 42%	2/8 p.m.	—	+*	+	—	—	—	—	—	—	—	—	—	+	+*	—	—	—	+
8	demeton, 1 pt. 42%	2/11 a.m.	+*	+	+*	—	—	—	—	—	—	—	—		+	+*		—		+
8	demeton, 1 pt. 42%	2/12 p.m.			+	+*	—	+	—	—	—	—	—		+	+*		—		+

[1] Detailed spray program shown in Table 1.
[2] Taster R made tests at later dates but in same order.

TABLE 5

Single sample taste test on apples—1953. (+ indicates foreign flavor, +° indicates trace foreign flavor only, — indicates no foreign flavor.)

Plot [1] No.	Treatment [1]	Variety	Date of test (1954)	Taster						
				A	B	C	D	E	F	G
3	control	Delicious	5/5 p.m.	—	—	—	—	—	—	+°
3	control	Delicious	5/7 a.m.	—	—	—	—	—	—	—
3	control	Delicious	5/12 a.m.	—	—	—	—	[2]	[2]	[2]
3	control	Winesap	5/6 p.m.	—	—	—	—	—	—	+°
3	control	Winesap	5/10 a.m.	—	—	—	—	—	+°	—
3	control	Winesap	5/11 a.m.	—	—	—	—	—	+°	—
2	demeton, 1 pt.	Delicious	5/5 a.m.	+	+	+	+	—	—	—
2	demeton, 1 pt.	Delicious	5/10 p.m.	+	—	+	+°	—	—	—
2	demeton, 1 pt.	Delicious	5/12 p.m.	+	+	+	+	[2]	[2]	[2]
2	demeton, 1 pt.	Winesap	5/6 a.m.	—	+°	+	+	—	+°	—
2	demeton, 1 pt.	Winesap	5/7 p.m.	+	—	+	+	—	—	—
2	demeton, 1 pt.	Winesap	5/11 p.m.	+	+°	—	+	—	—	—

[1] Detailed spray program shown in Table 1.
[2] Insufficient samples prevented these tasters from participating in tests indicated.

sults obtained with an unselected panel were not significant, the philosophy of the single-sample method requires that the tests be repeated with any taster showing an apparent sensitivity to determine if the sensitivity were real. The single-sample method is intended to determine if any individuals are sensitive to the flavor being studied. When no taster appears sensitive, a decision as to the absence of foreign flavor is limited by the size of the panel used.

Repetition of the tests with judges selected from a single-sample panel would also tend to eliminate individuals who consider as foreign certain flavors not related to the treatment under study. Their elimination would minimize the occurrence of foreign flavor judgments in untreated samples which are most frequent when the material under study includes a range of quality. The problem of foreign flavor scores appearing in untreated samples and of preferences being expressed for treated samples has been encountered by other workers *(4, 5, 8, 11)*.

Tasters A through E and taster R from the panel used in the juice test were selected to taste fresh apples (Table 5), together with a member of this laboratory who did not participate in the juice tests. The data show that four of this group, A through D, were quite consistent in detecting a foreign flavor in the treated apples. Taster E did not detect a foreign flavor in any sample, while tasters F and G indicated a trace of foreign flavor in some of both the treated and untreated samples. Unless it were detected as a trace only, most tasters considered the foreign flavor objectionable and did not finish the sample. Statistical analysis of the data from all of the tasters in this test showed detection of a foreign flavor to be significant at the 1% level.

SUMMARY AND CONCLUSIONS

A single-sample taste method is described that appears to have special merit in the detection of at least some types of foreign flavors. Some problems connected with taste-panel evaluation of insecticide-induced foreign flavors are discussed.

Results by the single-sample method show that apples treated with demeton and juice prepared from demeton-treated apples have a detectable foreign flavor. Results of the triangle difference method on the same series of juice samples were inconclusive.

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Factors in Processing Methods Which Affect the Quality of Dehydrofrozen Apple Slices[a]

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Through use of rapidly penetrating sulfurous-acid dipping solutions, and high relative humidities in the drying air, methods have been worked out for preparation of dehydrofrozen apple slices which are free from internal browning and contain low concentrations of sulfur dioxide. Effects of variations in sulfite treatment and dehydration upon quality of product have been determined.

Dehydrofreezing of apple slices consists essentially of drying sulfited slices to about 50% of original weight and freezing the packaged product. Methods that can be used in preparation of dehydrofrozen apple products have been published *(10)*. A full discussion of processing factors that may affect quality has been held in abeyance until findings could be verified over a period of several years with varieties commonly used in pie stock.

This paper reports a critical examination of two steps: impregnation of slices with sulfur dioxide and dehydration of sulfited slices. These steps can be combined with little difficulty to produce a dehydrofrozen product free from internal browning and containing as little as 40 p.p.m. of sulfur dioxide. Such combination, however, requires a working knowledge of factors affecting (a) penetration of sulfur dioxide to the center of a slice and (b) removal in the drier of surplus sulfur dioxide. Essentially, the problem is one of establishing conditions that favor a high degree of mobility of sulfur dioxide through apple tissue.

Conventionally frozen apple slices contain comparatively high levels of sulfur dioxide (200 to 400 p.p.m.). To prevent internal browning, fairly high levels must be absorbed in the sulfite tank and sufficient time (6 to 24 hours) must be allowed in the package before freezing for penetration to the center of each slice. Conventionally dehydrated apple slices, after rehydration, contain equally high levels. Internal and external browning during storage are prevented by treatment with high concentrations of sulfur dioxide gas before and after dehydration. The low levels (20 to 40 p.p.m. on a rehydrated basis), obtainable in dehydrofrozen slices, make the product particularly attractive for use in pie stock, because the average person cannot detect sulfur dioxide at levels below 40 to 50 p.p.m.

Factors influencing movements of SO_2 *into* and *out of* apple tissue during processing are discussed separately because experimental evidence has shown that factors of greatest importance in movement in one direction are of little importance in movement in the other. Complete penetration (and prevention of subsequent internal browning) is influenced chiefly by events in the sulfite tank. Although most of the penetration takes place early in the drying cycle (Figure 1), temperature and moisture conditions within the drier have little effect upon the presence or absence of brown centers in the product. Removal of surplus SO_2 from a slice is influenced chiefly by events within the drier. It is related to sulfite treatment only in that residual SO_2 in a dried slice is proportional to that in a slice before dehydration, a factor that is inconsequential in comparison with other factors involved in drying.

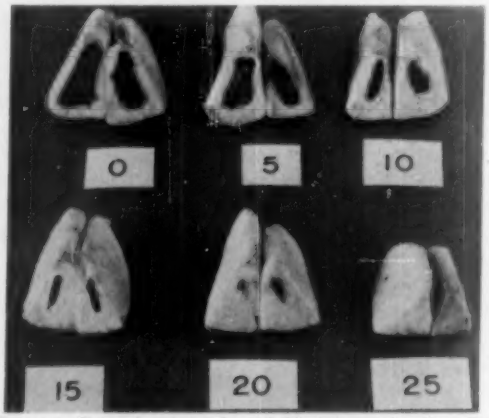

Figure 1. Rate of penetration of SO_2 into apple slices during drying.

METHODS

Raw material. Basic investigations of factors affecting movement of sulfur dioxide through apple tissue were carried out with large quantities of two grades (a combination, Fancy and Extra Fancy grade, and a C grade)[b] and 4 sizes (covering the range of 100 to 150 apples per box) of 3 varieties (Jonathan, Winesap, and Delicious). Fruit was obtained from a single commercial orchard near Yakima, Washington, in 1947, so that experiments would be affected as little as possible by variations in raw material. Subsequently, samples of these and other important varieties of Western apples were used to verify the findings. Experiments with Eastern-grown apples were limited by quarantine regulations of the State of California.

Processing. Apples were peeled and cored in a hand-operated commercial-type peeler, hand trimmed, and immediately placed in a 1.0% sodium chloride solution to prevent surface browning. As soon as a sufficient quantity for two drying trays had been prepared, the apples were cut into conventional 1/12 radial sections (wedges) and placed in a wire-mesh basket. The basket was immersed in an aqueous solution (60 to 70° F.) of sulfur dioxide. After removal, slices were loaded in a single layer on stainless-steel, wire-mesh trays (2 x 3 ft.) with a tray loading of 1.5 pounds per square foot, placed in a cross-flow cabinet

[a] Presented at the Fifteenth Annual Meeting of the IFT, Columbus, Ohio, June 12-16, 1955.

[b] C grade apples as graded in the Pacific Northwest are those apples which have been graded down on the basis of color.

drier, and dehydrated to 50% of original weight. The drier was operated at an air velocity of 900 ± 50 linear ft./min. and at pre-set wet- and dry-bulb temperatures. In studies involving sulfur-dioxide penetration, these settings were held constant at 130° and 180° F., respectively. Concentrations of sulfur dioxide in the sulfiting tank, freshly sulfited slices, and dehydrated slices were measured by the method of Ponting and Johnson *(7)*. This method measures the total of both free sulfur dioxide and sulfur dioxide bound to sugars and aldehydes.

In studies involving sulfur dioxide removal, Winesap apples of a uniform grade and size were used in all tests except those involving two-cycle drier runs. Slices were sulfited at values (0.6% solution of sulfur dioxide and 1.5 minutes' retention time in the tank) which would result in about 4% of slices showing internal browning, when the slices were dehydrated at 180° F. dry bulb and 130° F. wet bulb. These conditions were chosen so that effects of different wet- and dry-bulb settings upon internal browning could be observed. Jonathan apples, sulfited in 0.4% solution for 0.5 minute, were used in tests involving two-cycle experiments.

Candling. Under the conditions used, areas of the slices where sulfur dioxide had not penetrated invariably darkened before completion of drying. Slices that did not darken during partial dehydration did not darken subsequently in freezing storage and after thawing. Thus, it was possible to ascertain the extent of sulfur dioxide penetration in each individual slice (and the number of slices affected) by candling (passing a strong light through slices and observing the presence or absence of internal darkening). This procedure was used in preference to the spot catechol test *(6)*, since the number of darkened slices could be determined more rapidly and without destruction of samples. All slices on a tray (about 200) showing any trace of darkening were counted and results expressed in percentage. The spot catechol test was used to determine depth of penetration prior to and during early stages of dehydration (Figure 1).

Internal piece temperatures. Internal-piece temperatures were measured by an iron-constantan thermocouple in the center of each of 3 slices, placed in chosen locations on a tray, to record changes during drying.

Rates of loss of water and SO_2 during dehydration. Three hundred grams of sulfited slices were placed on each of the ten 8-inch-square trays. Trays were placed on a larger tray and inserted in the drier. Individual trays were removed at intervals, weighed, and slices were analyzed for sulfur dioxide concentration.

FACTORS AFFECTING PENETRATION OF SULFUR DIOXIDE

Under the operating conditions chosen for these studies (application of findings in a continuous porcess), most of the penetration takes place after drying has commenced (Figure 1). Hence, the ultimate depth was determined in dehydrated slices. Use of holding periods sufficient for completion of penetration prior to drying were not considered seriously because of higher commercial costs (floor space, labor, etc.) and inferior product quality (see section on Relation Between Delays in Processing and Loss of Sulfur Dioxide During Dehydration).

Minimum treatment needed to prevent internal browning. The effects of solution concentration and retention time in the sulfiting tank upon penetration were examined to determine, for each variety, the minimum treatment resulting in no internal browning concomitant with low levels of sulfur dioxide in the product. Combinations of 3 levels of sulfur dioxide (0.2, 0.4, and 0.6%) and retention times from 0.5 to 5.0 minutes were used.

The values in Table 1 represent minimum treatments for specific lots of apples. All values resulted in acceptably low concentrations of sulfur dioxide in the product. Values for other lots of these varieties will vary with ripeness and other factors. Selections were made from experimentally determined curves (Figures 2 and 3) and were based upon a compromise between factors that affect commercial use of the information. Higher concentrations of sulfur dioxide produce more rapid penetration, but time of immersion may become too short for adequate control, while longer retention will increase proportionately the size of the sulfiting tank.

TABLE 1
Minimum sulfur dioxide treatment for four varieties of apple slices

Variety	Maturity	SO_2 concentration in bath (%)	Immersion time (min.)
Jonathan	ripe	0.4	2
Winesap	firm	0.6	2½
Delicious	firm ripe	0.6	2
Newtown Pippin	firm	0.6	2½

Effect of time and concentration upon absorption of sulfur dioxide. Direct mathematical relationships were found between increases in time or concentration during treatment and resultant levels of sulfur dioxide in slices analyzed directly after treatment. If the sulfur dioxide level resulting from a given treatment is known, the new level resulting from an increase in concentration (time of treatment held constant) can be computed by:

$$C_1 = C_0 (N_s)^{3.32 \log_{10}(S_1/S_0)}$$

and the level, resulting from an increase in time of treatment, (concentration held constant) can be computed by

$$C_1 = C_0 (N_t)^{3.32 \log_{10}(t_1/t_0)}$$

where: C_0 = level of SO_2 in slices resulting from original treatment (p.p.m.)
C_1 = level of SO_2 in slices resulting from an increase in time or concentration (p.p.m.)
S_0 = original concentration of SO_2 in the tank (p.p.m.)
S_1 = proposed higher concentration of SO_2 in the tank (p.p.m.)
t_0 = original time of treatment (min.)
t_1 = proposed longer time of treatment (min.)
N_s = increment of concentration in slices due to increase in solution concentration $(C_1 - C_0)/C_0$
N_t = increment of concentration in slices due to increase in time of treatment $(C_1 - C_0)/C_0$

Experimental values of N_s ranged from 2.0 to 2.2 and those of N_t from 1.4 to 1.5.

These relationships permit prior computation and make it possible for the processor to avoid trial and error methods. As values of N_s are considerably higher than those of N_t, browning can be eliminated by a smaller increase, percentagewise, in solution concentration than in time of treatment. Figure 3 emphasizes this point. This characteristic is advantageous to the processor, as it is usually much simpler to adjust solution concentration than to change speed of passage through a tank.

Effect of solids build-up in the sulfite tank. When apple slices are immersed on a commercial production line, apple juice, small pieces of apple, and soluble solids leached from slices accumulate in the sulfiting tank. An extreme case of such accumulation (where concentration in the dip approaches that in the apple itself) was used to determine effect upon penetra-

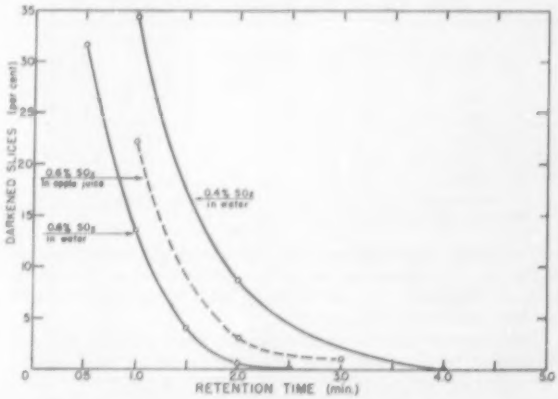

Figure 2. Effects of retention time and SO_2 concentration of two different types of solutions upon internal darkening during drying—Winesap.

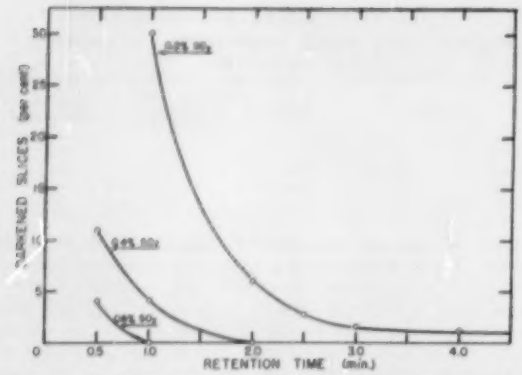

Figure 3. Effects of retention time and SO_2 concentration in sulfiting tank upon internal darkening during drying—Jonathan.

tion. Freshly pressed Winesap juice was used as the solvent in preparation of a solution containing 0.6% sulfur dioxide. Winesap slices similar to those used in determination of the water-immersion curves in Figure 2 were treated in this solution for periods of 1, 2, and 3 minutes.

Penetration was somewhat slower as measured by percentage of darkened slices in the product (Figure 2), but neither the quantity of SO_2 absorbed before nor that remaining after dehydration was affected to any extent. In this extreme case, a compensatory increase of about 30% in concentration of SO_2 in the tank would be required. Solids build-up to this degree is approached in practice only when a tank is used for several days without refilling, or where the quantity of slices treated is large in comparison with volume of solution. The degree of compensation ordinarily required lies within the factor of safety used in setting SO_2 concentration limits for the sulfiting tank.

Effect of pH of sulfiting solution. The type of solution used determines to a large extent whether or not prolonged delay is needed before dehydration, as the pH of the solution has been found to affect markedly the rate at which SO_2 penetrates a slice. In some applications (such as sulfite treatment for freezing preservation) sodium sulfite, sodium metabisulfite, sodium bisulfite, or these acidified with citric or hydrochloric acids have been recommended for use *(7, 9)* in conjunction with a delay period of some hours at ambient temperature before freezing.

It has been reported *(9)* that rate of penetration can be increased by lowering the pH of a sodium bisulfite solution (e.g., pH 3 with citric acid) and further increased by use of a sulfurous acid solution. Experiments such as those reported in Table 2 have shown that penetration is so much more rapid

TABLE 2

Effect of type of sulfur dioxide solution upon penetration of sulfur dioxide into Winesap apple slices

Source of SO_2 [1]	pH	Immersion time (min.)	SO_2 in slices (p.p.m.) directly after dip	Darkened slices %
Sulfurous Acid	1.45	1	580	14
Sodium bisulfite [2]	3.00	1	670	72
Sulfurous Acid	1.45	2	830	0.5
Sodium bisulfite [2]	3.00	2	850	50

[1] All solutions contained equivalent of 0.6% sulfur dioxide.
[2] Adjusted with citric acid.

with sulfurous acid solutions that the customary holding period usually can be eliminated and slices processed in a continuous manner. Therefore, use of solutions other than sulfurous acid was not considered to be practical.

The observed inverse relationship between solution pH and penetration rates appears to be due to shifts in the equilibrium:

$$\text{Free } SO_2 \rightleftharpoons H_2SO_3 \rightleftharpoons (HSO_3^-) \rightleftharpoons (SO_3^=).$$

Calculations based upon experimental pH values of aqueous solutions of SO_2 gas in concentrations of 0.1 to 0.6% and upon ionization constants of H_2SO_3 show that practically no free SO_2 exists in these solutions, that approximately one-third of the acid has undergone primary ionization and that there is practically no secondary ionization. Hence, the vapor pressure of SO_2 at solution boundaries is related directly to the concentration of undissociated H_2SO_3 in the solution. The concentration of undissociated H_2SO_3 (and therefore the vapor pressure of SO_2) will diminish rapidly as the pH of the solution is raised by the addition of NaOH, for a considerable amount of $SO_3^=$ ion is formed during partial neutralization. Conversely, acidification of a $NaHSO_3$ solution will result in an increase in concentration of undissociated H_2SO_3. Experimental evidence indicates that the degree of penetration of sulfur dioxide into apple slices is proportional to vapor pressure of SO_2 at solution boundaries which, in turn, is inversely proportional to the pH of the solution. The observed rapid rate of penetration into apple tissue after completion of sulfite treatment at low pH values can be interpreted similarly, as the pH at or near the surface of a slice undoubtedly is influenced by the pH of the sulfiting solution.

Effect of other factors. The size of apple used has not been an important consideration, except in isolated cases. Processors keep the size of wedges relatively uniform by varying the number of cuts with size of the apple. Hence, piece-to-piece variation due to off-center coring usually more than offsets the variation in piece sizes resulting from differences in apple diameter.

The effects of differing degrees of maturity (on the tree) and ripeness (after harvest), as measured by pressure test *(4)*, of trueness of varietal strain, of local soil and climatic conditions, and of pre-processing storage conditions upon penetration have not been investigated but are well known to experienced processors. Isolated instances indicate that certain factors (immaturity or low-humidity storage) will lessen rates of penetration while others, notably ripening, will tend to speed up rates.

FACTORS AFFECTING REMOVAL OF SURPLUS SULFUR DIOXIDE

It was necessary to examine factors that affect removal of surplus sulfur dioxide from apple slices in order to develop dependable methods for reducing the initial concentrations of 250 to 700 p.p.m to levels (40 to 80 p.p.m.) desired. As reduction takes place primarily through volatilization of SO_2 from the surface, events prior to and during dehydration that might affect rate were investigated. Reduction of sulfur dioxide concentrations through oxidation of sulfite to sulfate was not considered important, because the rate of this reaction under normal processing conditions is too slow.

The principles involved in conventional dehydration of fruits have been widely investigated *(1, 12)*, particularly as applied to prunes *(2, 5)* and apples *(3)*. However, problems encountered in dehydration of apple slices for dehydrofreezing differ in two important respects. First, dehydration is carried only as far as 50 to 60% weight reduction, with the result that only the first phase of drying is involved (constant ratio between time and amount of water removed). During this phase, the surface of evaporation has been stated *(1, 12)* to be controllable by variation in relative humidity of the drying air. Second, investigators have not been interested in removal of the maximum amount of SO_2 from the product but rather in maximum retention.

Surface texture, relative humidity, and loss of sulfur dioxide during dehydration. The relationship between state of surface and residual concentration of SO_2 in the product was examined by comparing levels of SO_2 in dried slices resulting from use of various wet- and dry-bulb settings during dehydration. Combinations of wet-bulb values from 110° to 170° F. and dry-bulb values from 180° to 200° F. were used. Slices were dehydrated to 50% of original weight and state of surface was examined directly after removal from the drier.

The surface changed markedly as relative humidity (RH) was lowered. At RH values near or above 30%, the surface was moist, open in texture, and relatively unchanged in appearance from that of a freshly cut slice. As the RH value was lowered, the surface became denser and less moist. At values near 10%, the surface layers were dry, rubbery, and could be peeled from the inner, moist tissue. Excessive surface dehydration was reversible, however, for slices dried at low RH values would

usually equilibrate after standing at room temperature for an hour or so.

The concentration of SO_2 in the dehydrated product was found to vary inversely with the RH employed in drying (Figure 4), probably as a result of changes in the surface of evaporation. The curve indicates that the relationship is nearly linear until the RH has been raised to the value where an open, moist surface is obtained (about 30%). The curve above this value is similar to curves representing rate of penetration of a gas through a permeable material.

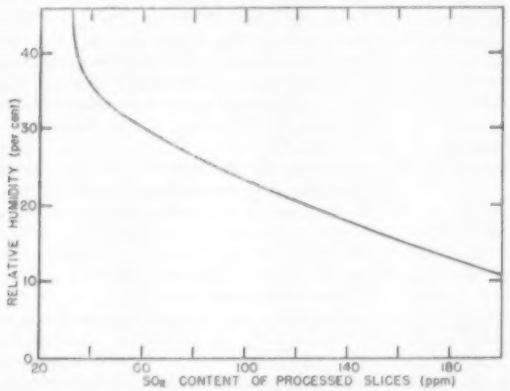

Figure 4. Effect of relative humidity upon concentration of sulfur dioxide in apple slices dehydrated to 50% of original weight.

Recommended limits of RH for use in drying apple slices for dehydrofreezing are presented in Figure 5. Use of dry-bulb values below 180° F. is not recommended, because drying time is unnecessarily extended, while values above 220° F. may result in scorching of partially dried slices.

The effect of changes in surface texture (as caused by changes in RH values) upon the comparative rates of loss of water and sulfur dioxide was investigated in order to examine more thoroughly the events during dehydration. Amounts of water and SO_2 remaining were determined on aliquots removed from the drier after stated intervals. As expected, a constant ratio was found between time and amount of water removed, while total time needed to dehydrate to 50% of original weight lengthened as the RH value was raised. Initially, loss of sulfur dioxide was very rapid (about 50% in 5 minutes) and seemed

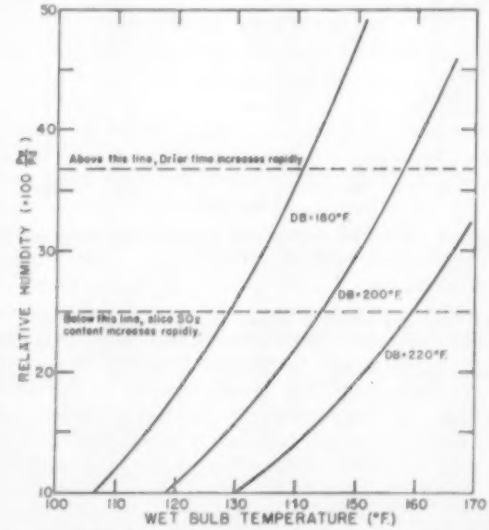

Figure 5. Relative humidity limits recommended for drying of sulfited apple slices.

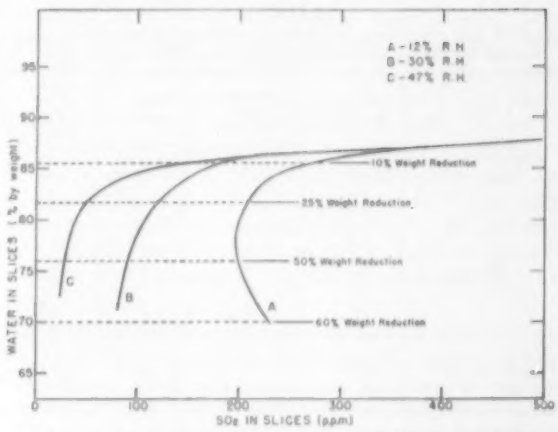

Figure 6. Relation between moisture and SO_2 in apple slices dried at different relative humidities.

to be unaffected by the RH value used. However, marked differences in rate of loss of SO_2 soon appeared, due to changes in surface texture as a result of the particular RH employed. In slices dried at 10% RH, rate of loss dropped so markedly near the end of dehydration (Figure 6) that an apparent increase in concentration took place. The tests indicate that a definite period is needed for the development of the type of surface resulting from use of low RH.

Figure 7 illustrates the influence of RH upon the rate of loss of SO_2 during dehydration. Curves A and B show rates obtained at low and high RH, respectively. Curves C, D, and E show that, when RH was changed during dehydration, rate of loss was altered, and the curve became similar to the terminal portion of the curve (A or B) which represented full dehydration at the new RH value.

The concentration of SO_2 in the product was found to be proportional to that present in slices entering the drier. The ratio of residual to original concentration averaged 1:6 for slices dried at 25 to 30% RH and 1:2.5 for those dried at about 10% RH. For slices delayed between sulfite treatment and dehydration, the ratio tended to fall and was a function of time of delay (see below).

Relative humidity, internal piece temperatures, and rates of dehydration. The RH of drying air has a marked effect upon temperature changes within a slice. Conditions that favor dry, rubbery surfaces (RH 10% or lower) result in a slow "come up" time to a temperature approaching that of the wet-bulb in a finishing temperature considerably above this point (Figure 8). Conditions that favor maintenance of a moist, porous surface

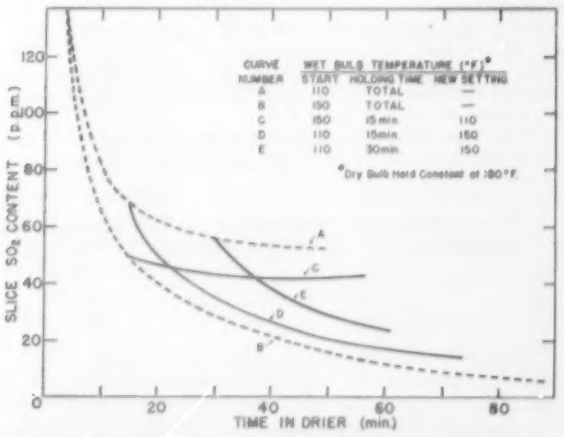

Figure 7. Effects of two-stage drying to 50% weight reduction upon rate of SO_2 removal from apple slices.

TABLE 3

Effect of delay between sulfite treatment and dehydration upon residual sulfur dioxide concentration in sulfited apple slices

Variety	SO_2 (%) in bath	Immersion time (min.)	Delay (min.)	SO_2 in slices (p.p.m.) final
Jonathan	0.2	2	0	20
	0.2	2	10	40
	0.4	1	0	45
	0.4	1	10	120
	0.6	½	0	50
	0.6	½	10	170
Newtown Pippin	0.4	2	0	80
	0.4	2	10	95
	0.4	2	90	125
	0.4	2	300	144

(RH 25 to 30% or higher) result in a more rapid "come up" time and in a finishing temperature only slightly higher than that of the wet bulb (behavior similar to that of the moist wick of a wet-bulb thermometer).

The least RH value (about 27%) at which the latter condition is obtained can be considered as indicating an equilibrium between rate of moisture diffusion through apple flesh and rate of moisture evaporation from the surface. Maintenance of this equilibrium does not seem to be important as far as water removal is concerned, for no change in rate of moisture loss during a run was observed at low RH values. However, maintenance of such a state during dehydration of sulfited slices is important in order to provide a surface that is easily permeable to SO_2.

An undesirable feature is that, at a given dry-bulb temperature, dehydration must be carried out at high RH to effect adequate removal of SO_2. This increases the time required (Figure 9). Preheating of slices by raising internal piece temperatures at a very rapid rate to a value approximating the required high wet-bulb temperature should result in more efficient drier utilization, because a greater proportion of the heat in the air stream can be utilized for evaporation. Rapid heating of a mass of cool slices at the entrance of a continuous drier can be accomplished by exposing the mass to hot, moist air (>100% RH) under conditions of time of exposure and wet-bulb temperature so that internal piece temperature approximates that required during dehydration and so that excessive condensation does not occur. In this procedure, advantage is taken of the fact that wet-bulb temperature governs the maximum internal piece temperature when RH values in excess of 25 to 30% are used (Figure 8). The essential requirement is that wet-bulb temperature in excess of that required for dehydration and RH above the range of 25 to 30% be used for preheating in order to raise internal temperature as rapidly as possible. Preheating can be accomplished in a separate unit at the entrance to a drier or incorporated into the first part of the drier unit.

Drying time can also be shortened by 4 types of variation in wet- and dry-bulb values. These alternatives (A, B, C, and D), based upon reference conditions of 26% RH (180/130), are indicated in Figure 9 and the effects upon drying time, RH, and SO_2 content are listed in Table 4.

Of the four alternatives, only C results in maintenance of an equally low concentration of SO_2 in the product. This approach can be used to shorten drying time in cases where residual concentration is appreciably less than is required to meet grade standards (e.g., easily penetrable varieties or soft ripe fruit).

Influence of drying factors upon internal browning. Unsulfited apple slices can be dehydrated to 50% of original weight without internal browning, provided internal temperatures do not exceed 115 to 120° F. Slices prepared thus will develop internal browning subsequent to freezing unless some means such as heating is employed for inactivation of enzymes responsible for browning.

Lightly sulfited slices (150 to 200 p.p.m.) can be dried at low temperatures (150° F. dry-bulb and 90° F. wet-bulb) and complete penetration obtained after dehydration by use of a long holding period at room temperature. The procedure, however, is time consuming; drying time is lengthened considerably; residual concentrations of sulfur dioxide are not sufficiently low, and internal browning may be a problem due to variations in sulfiting and drying procedures.

Browning will occur during dehydration in unpenetrated areas of a slice when internal piece temperatures exceed approximately 115 to 120° F. As most of the penetration occurs within the drier (Figure 1), the occurrence of browning from lack of penetration should be influenced by changes in internal piece temperatures resulting from use of different RH values. However, it appears that these influences (acceleration of penetration due to higher temperatures and elapsed time to reach 115 to 120° F.) are self-compensatory, for within the range of drying conditions examined (RH 10 to 40% and dry-bulb temperatures 180 to 220° F.), no measurable changes in the percentage

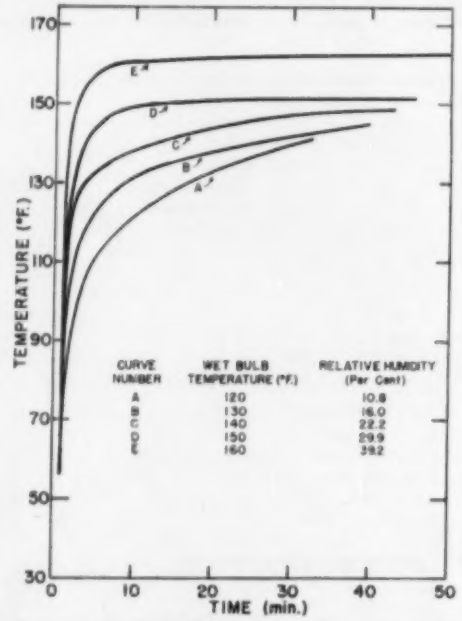

Figure 8. Effect of various wet bulb settings upon internal piece temperatures at 200° F. dry bulb.

TABLE 4

Effects of various wet and dry bulb temperatures upon drying time and residual sulfur dioxide content

Setting no.	Change	Dry bulb	Wet bulb	Relative humidity	SO_2 content of dried slices	Drying time	Reduction in time
		(° F.)	(° F.)	(%)	(p.p.m.)	(min.)	(%)
Initial		180	130	26	90	50	—
A	Lower Wet Bulb 20° F.	180[1]	110	12	188	42	16.0
B	Raise Dry Bulb 20° F.	200	130[1]	16	150	37	26.0
C	Raise Dry Bulb 20° F. while holding relative humidity constant	200	145	26[1]	90	39	22.0
D	Raise Dry Bulb 20° F. and lower wet bulb 20° F.	200	110	7.5	230	32	36.0

[1] Denotes item held constant.

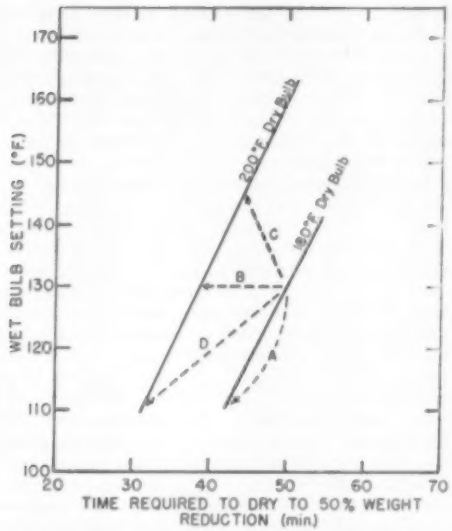

Figure 9. Effect of wet and dry bulb settings upon dehydration rates.

of internal browning were observed that were related to events during dehydration.

Delays in processing and loss of sulfur dioxide during dehydration. Delays between sulfite treatment and dehydration result in higher levels of SO_2 in the product than would otherwise be obtained. Table 3 illustrates the two extremes that may be encountered in practice (soft Jonathans and firm Pippins). The relationship between delay *(t)* and increase in concentration of SO_2 in the product *(C)* may be expressed as: Log $(t) = k_1 C - k_2$. The first constant (k_1) is related to the ripeness and penetrability of the particular fruit and the second (k_2) to the conditions (time and concentration) used in sulfite treatment. The formula, which is similar in form to those expressing penetration rates of gases or liquids into penetrable materials, indicates that increase in SO_2 concentration can be explained on the basis of the average distance the chemical must travel to leave the fruit during dehydration. Initially, SO_2 is concentrated in a narrow band close to the surface. During a holding period, the band widens as the gas penetrates, thereby increasing the distance that the average molecule of SO_2 must travel to leave the slice.

INDUSTRIAL APPLICATIONS

The preparation of a high-quality dehydrofrozen product is not difficult, provided equipment and methods are designed to take advantage of factors affecting movement of sulfur dioxide. Transition from laboratory-scale, batch-type experiments to commercial-scale, continuous production involves changes that are important to the prospective manufacturer.

A product containing a uniformly low concentration of sulfur dioxide requires that slices receive fairly uniform treatment in the sulfite tank. The usual tank, in which slices float on the solution, is unsuitable. A certain proportion of slices is forced above the solution at any given time and absorb far less sulfur dioxide. Uniformity can be obtained by installing a belt so designed that slices are held beneath the surface. Rate of passage can be altered by changing the speed of the belt. Mild agitation is needed to maintain uniformity in concentration throughout the tank.

The odor of sulfur dioxide around a tank containing sulfurous acid is far stronger than that encountered with solutions of higher pH. Hence, precautions are needed to protect workers and equipment. The sulfiting tank should be isolated by partitions and an exhaust fan installed for removal of gas.

The odor from sulfited slices is likewise stronger and may interfere with inspection after treatment. Installation of a curtain type of water spray (about 0.5 gallon of water/minute/foot of belt width at a belt speed of 30 ft./min.) between the tank and the inspection belt will reduce odors to an acceptably low lovel. An increase of 10 to 15% in SO_2 concentration in the tank may be required to compensate for that washed off by the spray.

Under certain circumstances, it may be desirable or necessary to hold sulfited slices before insertion in the dehydrator. The quantity of sulfur dioxide in the product will increase at a rate proportional to the log of time of delay, but in the usual case (relatively firm apple slices) will not be affected materially by delays of one hour or less. With certain types (immature, unripened Rhode Island Greening or Newtown Pippin) which are very resistant to penetration by SO_2, a milder treatment combined with a long delay may result in lower concentration in the product than can be obtained by drying directly after treatment.

Space and cost factors indicate that apple slices can be dehydrated most economically in a bed, several layers deep, in a continuous drier. This can be accomplished in a rotary drier *(8)* where slices continuously change position in relation to air stream or in a drier, where a static mass passes through one or more drying zones.

Conditions to which a mass of slices are exposed in a rotary drier differ markedly from those to which a single, stationary lever are exposed. In a rotary drier, the RH of entering air rises rapidly from absorption of vapor as air passes through the bed. Slices are exposed alternately to high and low RH conditions and do not remain in a zone of low RH for an appreciable period. A definite time appears to be necessary for the formation of toughened surface layers; hence, it is quite possible that the average RH value in the bed needed to prevent surface toughening may be somewhat lower than that needed during dehydration of a single, stationary layer. Furthermore, the RH value of the entering air used in a rotary drier can well be appreciably lower than that used with a simple, stationary bed of slices, because the average RH value in the bed rather than that of the entering air is most important in removal of SO_2.

CONCLUSIONS

Enzymatic internal browning during partial dehydration of sulfited apples in preparation for dehydrofreezing is influenced chiefly by events prior to dehydration. Rates of penetration of sulfur dioxide into slices can be increased, in order of importance, by lowering the pH of the sulfiting solution, increasing the concentration of sulfur dioxide in the solution, and increasing the time of treatment. Rate is retarded to some extent by the build-up of apple solids in the solution. The quantity of sulfur dioxide in the product (at constant wet- and dry-bulb settings in the drier) is mathematically related to differences in either solution concentration or immersion time.

Attainment of a low concentration of sulfur dioxide in the product depends primarily upon the type of surface maintained during dehydration. The least barrier to escape of sulfur dioxide results from use of relative humidity in the range of 25 to 30%. At lower values the rate of surface evaporation is faster than the rate of diffusion of moisture through a slice, and a dense surface, far less penetrable to sulfur dioxide, is produced. Holding periods between sulfite treatment and dehydration result in greater concentrations in the product. The increase is proportional to the log of the time of delay.

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Metallic Discoloration of Candied Fruits[a,b]

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The effects of metals and metal ions on color of artificially dyed candied cherries and water soluble dyes are described. Both artificial dyes and natural pigments are involved. Selective adsorption of metallic ions by fruit tissue is shown to occur.

The development of a satisfactory color is an important problem in the manufacture of artificially colored candied fruits. Undesirable colors may be caused by: (a) the use of improper varieties, (b) the use of overmature fruit, (c) excessive leaching of the brined stock to remove SO_2, and (d) reactions of metals and metal ions with fruit pigments and artificial dyes.

Atkinson and Strachan *(2)* noted that contamination by copper and iron gave rise to darkening of erythrosine dyed cherries and that tin reduced the color intensity of this dye. Further work by Atkinson *et al. (4)* established minimum copper concentrations producing discoloration with erythrosine dyed fruit at 8-10 p.p.m. These results were substantiated in the work of Butland *(5)*.

Cohee and Nelson *(6)* reported that an iron content in excess of 25 p.p.m. produced darkening in processed cherries damaged during growth or pickling. This discoloration apparently arose from formation of iron tannin complexes. Also it was shown that the iron discoloration was inhibited by the addition of the sequestering agent calcium phytate.

Aluminum discoloration of erythrosine dyed cherries was found by Atkinson *et al. (4)* to be insignificant when aluminum concentrations did not exceed 35 p.p.m. However, later work by Strachan and Kitson *(8)* showed that aluminum in concentrations of 100 p.p.m. and more caused severe discoloration of Ponceau dyed cherries.

The object of the present study was to obtain more specific information on the role of metals in the discoloration of candied fruits.

EXPERIMENTAL PROCEDURE

Candied cherries were prepared from standard SO_2 packed *(3)* Royal Ann cherries. The fruit was drained, pitted, leached and dyed according to the recommendations of this Laboratory *(4)*. In each test 250 g. of leached fruit was used. The finished weight of candied fruit and syrup was approximately 700 g. Erythrosine, ponceau 3R and ponceau SX dyes were employed. All samples were in the pH range of 3.6 to 3.9.

Addition of cupric ions. The degree of discoloration induced by cupric ions, in cherries treated with different dyes, was determined by adding copper sulfate to the candying syrup. Sufficient copper sulfate was used to provide cupric ion concentrations of 5-100 p.p.m. estimated on a finished weight of 700 g.

Efficiency of calcium phytate in reducing discoloration by ionic copper was determined by adding 2000 p.p.m. calcium phytate to samples containing 0, 20 and 40 p.p.m. of cupric ions.

Color of the finished product was noted. The copper content of both fruit and syrup were determined by the A.O.A.C. dithiocarbamate procedure *(1)*.

Addition of aluminum. To investigate the desirability of using aluminum equipment in a candied fruit line, samples of

[a] Presented at the Fifteenth Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 13, 1955.

[b] Contribution No. 284 of the Chemistry Division, Science Service, and No. 856 Horticulture Division, Experimental Farms Service, Canada Dept. of Agriculture.

candied cherries were processed with sections of aluminum plate suspended in the syrup. The ratio of metal surface to weight of fruit was 142 sq. cm. per 100 g. (100 sq. in. per pound). This would approximate the ratio of aluminum to fruit that might be encountered under commercial conditions. Samples were dyed with ponceau SX and erythrosine. To test the effect of the sequestering agents calcium phytate and disodium ethylendiamine tetraacetate (Na_2-EDTA), additional samples were processed in aluminum with these agents in the syrups. Calcium phytate was added at 100, 250 and 500 p.p.m. levels. Na_2-EDTA was used at concentrations of 500 and 1000 p.p.m.

The effect of increasing the dye concentrations to 3 times those normally employed was investigated as a means of overcoming metallic discoloration.

Aluminum in the finished cherries and syrup was determined by the colorimetric "aluminon" procedure of Snell and Snell *(7)*. The samples were judged visually for color.

Addition of tannin, lead and iron. Limited tests were made to determine the effect of tannin and ionic lead and iron on the color of ponceau dyed cherries. The metallic ions were added to the candying syrup to yield final concentrations of 20 p.p.m. in the fruit and syrup. Similarly tannin was added in a concentration of 1000 p.p.m. alone and in combination with the lead and iron salts.

Addition of iron, aluminum, and copper to aqueous solutions of artificial food dyes. Tests were made to measure any color changes arising from reduction of the dyes at metal surfaces. Twenty-five ml. aliquots of 0.0002 M amaranth, erythrosine, ponceau 3R, ponceau SX, brilliant blue and tartrazine were transferred to 100 ml. beakers and diluted to 50 ml. The solutions were adjusted to pH 3.5 to reproduce processing conditions. Strips of aluminum, copper and iron 2 sq. cm. in total surface area were placed in appropriate beakers. The samples were heated on a water bath at 130°-145° F. (54.4°-62.8° C.) for 7 days. An identical series of dye solutions was treated with 0.002 M solutions of $CuCl_2$, $FeCl_3$, and $AlCl_3$. Twenty-five ml. aliquots of the dye and metal ion solutions were mixed. The samples were adjusted to pH 3.5 and heated to 140° F. (60° C.). Following these treatments each solution was diluted to 100 ml. and optical density—wavelength curves were prepared using a Beckman Model B spectrophotometer.

RESULTS AND DISCUSSION

Effect of added cupric ions. Copper content of candied cherries processed in syrups with varying concentrations of added cupric ions is shown in Table 1. Cupric ions were adsorbed selectively by the fruit tissue in all cases where copper sulfate was added to the syrup. The table shows increasing copper content of the dyed fruit to be associated with increasing severity of discoloration. Severe darkening of undyed cherries also occurred at similar levels of added copper. These data indicate that darkening of the finished cherries arises from a reaction of cupric ions with natural pigments such as tannins and flavones present in the fruit.

Data in Table 2 indicate that although treatment with 2000 p.p.m. calcium phytate does inhibit discoloration by cupric ions it does not reduce the adsorption of the ions by the cherries.

Effect of aluminum. Cherries dyed with ponceau SX and candied in aluminum showed severe brown discoloration. The cherries contained 100 or more p.p.m. of aluminum. On the other hand cherries dyed

TABLE 1
Discoloration of dyed and undyed cherries by added Cu^{++}

Dye added	Cu^{++} added p.p.m.	Cu^{++} found in syrup p.p.m.	Cu^{++} found in cherries p.p.m.	Color of finished cherries
Erythrosine	0	0.6	1.3	Normal
Erythrosine	4.8	0.8	10.2	Slight change
Erythrosine	9.6	2.3	17.6	Distinctly bluer
Erythrosine	13.4	3.9	21.8	Slight browning
Erythrosine	24.5	5.6	49.5	Severe browning
Ponceau 3R	0	0.3	2.4	Normal
Ponceau 3R	9.5	1.1	18.5	V. slightly yellower
Ponceau 3R	18.9	2.9	40.5	Distinctly yellower
Ponceau 3R	37.7	8.2	58.9	Brown
Ponceau 3R	102.0	21.1	123.5	Dark brown
Ponceau SX	0	0.7	1.5	Normal
Ponceau SX	9.4	2.0	15.1	Slight change
Ponceau SX	23.6	2.8	25.6	Distinctly browner
Ponceau SX	44.8	7.8	40.7	Poor dye penetration, brown
Ponceau SX	97.0	12.3	102.0	Poor dye penetration, brown
None	0	0.4	3.3	Normal yellow
None	5.4	1.1	6.5	V. slightly greyer
None	10.2	2.3	18.3	Distinct greyish yellow
None	26.4	6.2	35.4	Dull greyish yellow
None	52.0	21.0	59.7	Dull brownish grey.

TABLE 2
Effect of calcium phytate on reduction of discoloration by added Cu^{++}

Calcium phytate added p.p.m.	Cu^{++} added p.p.m.	Cu^{++} found in syrup p.p.m.	Cu^{++} found in cherries p.p.m.	Color of finished cherries
0	0	0.7	1.5	normal
0	23.6	2.8	25.6	distinctly browner
0	44.8	7.8	40.7	brown, poor dye penetration
2000	0	0.5	1.7	normal
2000	21.0	6.6	18.5	normal
2000	43.7	13.6	56.7	v. slightly browner

TABLE 3
Effect of calcium phytate and ethylenediamine tetraacetate on reduction of discoloration of cherries candied in aluminum equipment

Dye	Treatment	Al. found in syrup p.p.m.	Al. found in cherries p.p.m.	Color of finished cherries
Ponceau SX	Al. no phytate	12	103	Unsatis. brown
Ponceau SX	Al. 500 p.p.m. phytate	15	132	Good color
Ponceau SX	Al. 250 p.p.m. phytate	—	—	Good color
Ponceau SX	Al. 1000 p.p.m. EDTA	—	—	Unsatis. brown
Ponceau SX	Glass	7	16	Good color
Erythrosine	Al. no phytate	14	154	Slight discoloration
Erythrosine	Al. 100 p.p.m. phytate	12	137	Good color
Erythrosine	Glass	7	16	Good color

TABLE 4
Effect of dye and dye concentration on color of cherries processed in aluminum equipment

Dye	Dye concentration g. per 100 lbs.	Color of finished cherries
Ponceau SX	12	Unsatisfactory brown
Ponceau SX	24	Unsatisfactory brown
Ponceau SX	36	Unsatisfactory brown
Erythrosine	5	Slight discoloration
Erythrosine	10	Good color
Erythrosine	15	Good color

TABLE 5
Color changes in dye solutions heated in presence of metals

Dye	Metal			
	Copper	Iron	Aluminum	Blank
Amaranth	Deep purple	Complete pptn.	Sl. more pink, less intense	No change
Ponceau 3R	Dark purplish brown	Complete pptn.	Less intense	No change
Ponceau SX	Dark reddish brown	Heavy pptn.	Less intense	No change
Brilliant blue	Dull greenish blue	Little change	Sl. less intense	No change
Tartrazine	Dark brownish yellow	Heavy pptn.	Sl. less intense	No change
Erythrosine	Darker pink v. sl. pptn.	Heavy pptn.	Sl. more pink, less intense	Some pptn.

with erythrosine were only very slightly discolored (Table 3).

Treatment of ponceau SX dyed cherries with 250 p.p.m. of calcium phytate prevented discoloration by aluminum. Disodium ethylenediamine tetraacetate was ineffective in concentrations up to 1000 p.p.m. These sequestering agents did not lessen the adsorption of aluminum ions by cherry tissue.

Increased concentrations of ponceau dye were ineffective in masking aluminum discoloration. With erythrosine dye, however, discoloration could be completely masked by increasing the dye application from 5 g. to 10 g. per 100 pounds of pitted fruit (Table 4).

Effect of tannin, lead and iron. At 20 p.p.m. neither iron nor lead ions affected color of fruit dyed with ponceau SX. Tannin at 1000 p.p.m. deleteriously affected the color. Combination of iron, lead, and tannin resulted in black cherries. This reaction indicates the role of tannin and similar natural pigments in discoloration by metals.

Effect of iron, aluminum, and copper on aqueous solutions of artificial food dyes. Color changes in candied cherries are partly due to reactions of ionic copper, aluminum, and iron with natural pigments in the fruit. However, considerable changes in colors of the artificial food dyes were found when dye solutions were heated to 130°-145° F. (54.4°-68.2° C.) at pH 3.5 in the presence of metal strips (Table 5).

Optical density—wavelength curves for the 6 dyes tested indicate that the presence of metallic iron will result in heavy precipitation and consequent reduction in color intensity of each dye except brilliant blue FCF. Metallic copper gave rise to shifts of absorption maxima of 30-40 mμ with tartrazine and amaranth. These shifts were toward the red and correspond to a darkening of observed color. With the ponceau dyes similar but smaller shifts of 15-20 mμ were noted. Metallic and ionic copper treatments produced definite intensification of the characteristic color of erythrosine. This corresponds to marked increases of optical density in the dye solutions. Treatment with aluminum metal did not give rise to absorption maxima shifts of more than 5 mμ with any of the dyes tested. It did, however, result in moderate to severe weakening of dye intensity in all cases.

Addition of ionic aluminum to dye solutions resulted in no significant changes of absorption curves of the ponceau dyes, amaranth or tartrazine. It did reduce the intensity of both brilliant blue FCF and erythrosine. Ferric ions caused a decrease in optical density of all dyes tested. Ionic copper also decreased the optical density of all dyes except erythrosine. The observed intensification of erythrosine color upon reaction with cupric ions is probably due to formation of a copper lake with the dye.

SUMMARY AND CONCLUSIONS

Effects of metal contaminants on the color of dyed and undyed candied cherries and dye solutions were determined. Ionic copper in concentrations exceeding 10 p.p.m. induced darkening of both dyed and non-dyed fruit. The color changes in undyed fruit suggest the formation of a copper complex with tannins or flavonoid compounds in the cherry tissue.

Copper added to syrup at the beginning of the candying process was adsorbed by the fruit. The adsorption rate was independent of the dyes and sequestering agents used. The addition of 2000 p.p.m. of calcium phytate was found, however, to reduce the discoloration caused by 57 p.p.m. of copper.

Cherries processed in the presence of aluminum showed marked discoloration with the exception of those dyed with erythrosine. The discoloration could be controlled in fruit dyed with ponceau SX by use of 250 p.p.m. calcium phytate. Disodium ethylenediamine tetraacetate proved ineffective as a sequestering agent when applied at the 1000 p.p.m. rate. The slight aluminum induced discoloration of erythrosine dyed cherries was best overcome by doubling the application of dye.

Reactions of solutions of amaranth, ponceau 3R and SX, erythrosine, tartrazine, and brilliant blue FCF with metals and metallic ions at pH 3.5 indicate that all these dyes with the exception of brilliant blue FCF are precipitated in the presence of metallic iron. They all undergo darkening in the presence of copper. Contact with metallic aluminum resulted in fading of all dyes tested.

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Increasing Shelf Life of Cereals with Phenolic Antioxidants[a]

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Samples of wheat germ meal, cream of corn, cream of oats, cream of rice, rice bran, brown rice and precooked breakfast cereals were treated with various combinations of butylated hydroxyanisole, butylated hydroxytoluene and propyl gallate. Various methods of applying these phenolic antioxidants were tried. All methods showed that these cereals can be stabilized against oxidative rancidity by the use of phenolic antioxidants.

Phenolic antioxidants such as butylated hydroxyanisole, butylated hydroxytoluene and propyl gallate have proved their usefulness in preventing oxidative rancidity in animal and vegetable fats. Magoffin and Bentz *(4)* showed that butylated hydroxyanisole and propyl gallate added to frying oils greatly increase the shelf life of potato chips. Cecil and Woodroof *(2)* found that peanuts and peanut butter can also be stabilized through the use of these phenolic antioxidants. Kraybill *et al. (3)* reported that butylated hydroxyanisole stabilized lard against oxidative rancidity. Lard thus stabilized was used to prepare potato chips, crackers, and pastries under laboratory conditions and crackers under commercial conditions. The stability carried over, they found, into the cooked product.

Some types of cereal grains, cereal flours, and breakfast cereals have a relatively short shelf life and soon lose the clear nutty odor and flavor normally associated with these products. Triebold *(10)* has shown that the stability of fats in baked cereal products is affected by various factors such as the amount of water and salt present, etc. He also cites the use of some natural antioxidants but states that none of them carry over into the baked product.

The oils normally found in cereals are similar in composition to the so-called commercial vegetable oils such as corn, cottonseed, peanuts, etc., and oxidize in much the same manner. Peters and Musher *(7)* have shown that oat flour has various antioxidant properties in its own right. Although it is well known that other cereal products contain natural antioxidants, these antioxidants apparently do not prevent the finished cereal from becoming rancid if storage after processing is involved.

Various United States patents *(1, 6, 8)* describe methods to prevent this oxidative type of breakdown in cereals. These patents indicate that several methods ranging from the use of synthetic and natural antioxidants to the physical coating of the cereal grains themselves have been tried. Although these methods have their uses, none is used commercially for various reasons. Since phenolic antioxidant combinations are now used successfully on various vegetable oils, it was postulated that dry cereals could also be stabilized, provided a method of application, practical under commercial conditions, could be found.

Phenolic antioxidants such as butylated hydroxyanisole (BHA), propyl gallate (PG) and butylated hydroxytoluene (BHT) are practically insoluble in water. They are soluble, however, in propylene glycol, vegetable oils, and most organic solvents. Since these antioxidants are normally used in extremely small quantities, a diluent must be used to effect complete distribution in a dry cereal product. The best approach for applying an antioxidant to food products such as wheat germ meal, brown rice, breakfast cereals, or similar products would probably be to either spray the antioxidant onto the product or blend it with the cereal in an agitator of some type. It was decided to apply the antioxidant as a concentrated solution, a diluted solution, or as a water in oil emulsion. Antioxidants in the solid form were not applied to the cereals due to the obvious difficulty of blending a waxy solid with a dry cereal.

METHODS

Experiment 1

In preliminary data two solvents were tried to dissolve various antioxidants. These solvents were ethanol and propylene glycol. It was found, however, that ethanol produced an odor and flavor in the finished cereal which could not be removed by drying. For this reason propylene glycol was used as the diluent in this trial. In this experiment and in all following experiments all antioxidants used were supplied from regular commercial production.[a]

Solutions of Tenox II antioxidant (a mixture of 20% BHA, 6% propyl gallate and 4% citric acid in propylene glycol), Tenox BHA antioxidant (pure butylated hydroxyanisole) and Tenox PG antioxidant (pure propyl gallate) were diluted with propylene glycol to contain 50% Tenox II antioxidant, 10% Tenox BHA antioxidant and 10% Tenox PG antioxidant.

Four 400-g. batches of a wheat germ procured locally were placed in a laboratory model Hobart Mixer and agitated slowly. The antioxidant solution was added dropwise to the agitating meal until a concentration of 0.05% Tenox II (0.01% BHA plus 0.003% PG plus 0.002% CA), 0.01% BHA or 0.01% PG based on the weight of the wheat meal were added to the mixture. After the antioxidant had been added to the mixture, agitation was continued for 30 minutes to assure complete dispersion. Propylene glycol alone was added to the control sample to nullify any antioxidant effect of this solvent. Three 2-ounce samples from each batch were placed in a Schaal Oven at 145° F. and tested daily by a trained organoleptic panel for evidence of rancidity. Shelf storage was not used in this particular experiment.

Experiment 2

The second experiment was conducted in the same manner as Experiment 1 except the antioxidant was added to the cereal in the form of a mist through the use of an atomizer. Commercial samples of cream of corn, cream of oats, cream of rice,

[a] Presented before the Fifteenth Annual Meeting of the Institute of Food Technologists, Columbus, Ohio, June 13, 1955.

[b] Subsidiary of Eastman Kodak Company, Rochester, New York.

[a] By the Tennessee Eastman Company.

and cream of barley were placed in a Hobart Mixer and agitated slowly. Tenox II antioxidant was placed in a small Devilbiss hand atomizer and without dilution was warmed to approximately 140° F. to reduce the viscosity of the solution. Samples (400 g.) of the above cereals were stabilized by spraying the warm Tenox II antioxidant into the agitating cereal until 0.05% Tenox II or 0.01% Tenox II based on the weight of the cereal had been applied to each sample. Control samples were sprayed with warm propylene glycol since this material is the solvent in Tenox II. Samples from each treatment were placed at 74° F. and examined bi-weekly for evidence of rancidity by an experienced organoleptic panel.

Experiment 3

Oil and water emulsions were prepared from Tenox VII antioxidant (28% BHA, 12% PG, and 6% citric acid in mixed glycerides) Tenox IV antioxidant (20% BHA and 20% BHT in vegetable oil) and Tenox VI antioxidant (10% BHA, 10% BHT, 6% PG and 6% citric acid in mixed glycerides). Three percent gum arabic was used as the emulsifying agent in this case.

Samples of brown rice and rice bran were spread in a thin layer on brown paper. Four hundred grams of each of these various samples were sprayed with the above emulsions using a Devilbiss hand atomizer. Sufficient emulsion was applied to each sample so they would contain 0.025% Tenox II (0.007% BHA plus 0.003% PG) 0.025% Tenox IV (0.005% BHA plus 0.005% BHT) and 0.07% Tenox VI (0.0035% BHA, 0.0035% BHT plus 0.006% PG). The samples were stirred by hand during the application to assure complete coverage. Control samples were sprayed with a dispersion of gum arabic in water. Samples were stored in duplicate at 145° F. and 74° F. and tested bi-weekly by an organoleptic panel for evidence of rancidity.

Experiment 4

It was believed that any batch method used for stabilizing cereals and cereal products would not be practical under commercial conditions. A method for continuously applying the antioxidant on potato chips after frying had been worked out by Dr. Ora Smith of the National Potato Chip Association. This method consisted of a Tenite plastic hood over a rubber conveyor belt. (See Figure 1.) A Devilbiss atomizer spray nozzle hooked to a continuous stream of air was fastened into the end of the hood in such a manner that the vapor stream would cover the entire belt for a length of approximately three feet. The conveyor belt was powered by a variable speed motor. Antioxidant was applied as a diluted solution in corn oil. With this type of equipment the concentration of the antioxidant on the product could be varied by one of several ways: (a) by varying the speed of the belt; ((b) by varying the air pressure on the atomizer nozzle; and (c) by varying the concentration of the antioxidant solution.

Figure 1. Laboratory equipment for continuous treatment of food products.

Stuckey *(9)* had previously shown that an increased shelf life in various types of candies could be obtained by treating the inner wrapper used in packaging the candy product. He found, however, that the greatest shelf life was obtained if the candy itself was treated with the antioxidant as well as the package in which it was wrapped.

The method of applying antioxidants to potato chips described above was considered applicable to cereal products. It was also believed that cereals could be stabilized by adding the antioxidant to the carton. Samples of fresh commercial precooked breakfast cereals were obtained and the following experiment undertaken to test these theories.

a. Group No. 1 was stored at 145° F. and 74° F. as received and was used as a control.

b. Group No. 2 was removed from the cartons and sprayed with a 10% solution of Tenox VI antioxidant in corn oil using the continuous belt described above. The concentration of the antioxidant was controlled so that 0.05% Tenox VI based on the total weight of the cereal was applied to the product.

c. Group No. 3 was removed from the cartons and the liners in each carton were replaced with a waxed glassine liner containing 0.05% Tenox BHA antioxidant. The cereal itself was returned to the box without treatment.

d. Group No. 4 was removed from the carton and the liners in each carton were replaced with liners similar to those described in Group 3. The cereal itself however was sprayed with Tenox VI as described in Group 2 in such a manner that it contained 0.05% Tenox VI.

Two 12-ounce packages, from each lot were stored at 74° F. and two stored at 145° F. Cartons were opened and examined bi-weekly by an organoleptic panel to determine rancidity.

A method of analysis was worked out for determining the antioxidant content of cereals and cereal products. This method is a modification of the method used by Mahon and Chapman *(5)* for the determination of BHA in lard but it is not within the scope of this paper to describe this method.

RESULTS AND DISCUSSION

Findings of the organoleptic panel in all of the tests indicate that there is a problem of rancidity in some dry cereal products even though they have an extremely low oil content. When rancidity was reached in those cereals tested, the odor and flavor of the product became exceedingly sharp and unappetizing. There was no evidence of off-odor or flavor in any of the treated lots which could be attributed to the small quantities of antioxidants used in this experiment.

Table 1 shows the results obtained when wheat germ meal was stabilized by blending the diluted antioxidant with the cereal in an ordinary Hobart type mixer. These data indicate that at 145° F. the synergistic mixture of BHA, propyl gallate and citric acid as formulated in the commercial Tenox II antioxidant was definitely superior to either the straight butylated hydroxyanisole or the straight propyl gallate. The BHA was more effective than the propyl gallate in this experiment.

TABLE 1

Stabilizing wheat germ meal by blending antioxidants

Treatment	Stability in days at 145° F.			
	A	B	C	Average
Control	6	6	6	6
0.05% Tenox II antioxidant	54	54	54	54
0.01% Tenox BHA antioxidant	27	26	28	27
0.01% Tenox PG antioxidant	18	18	18	18

In Experiment 2 the various commercial cereals were stabilized by blending them with the undiluted antioxidant. Table 2 shows that apparently this method is quite successful and a complete distribution of the antioxidant was obtained. It may be noted that 0.01% Tenox II gave practically equal results to 0.05% Tenox II based on the weight of the entire cereal. This indicates a very low oil content in these cereals and that with 0.01% Tenox II the maximum quantity of antioxidant necessary to stabilize these oils was reached. In every case, however, increases in the stability of the cereal were obtained regardless of the concentration of antioxidant used. It may also be seen from this table that the rapid storage test at 145° F. correlates quite closely with the room temperature storage at 74° F.

TABLE 2
Stabilizing cereals by blending antioxidants

Cereal	Treatment	Average stability in days at	
		145° F.	74° F.
Cream of corn	Control	12	60
	0.01% Tenox II antioxidant	28	77
	0.05% Tenox II antioxidant	33	78
Cream of oats	Control	40	90
	0.01% Tenox II antioxidant	50	175+
	0.05% Tenox II antioxidant	60	175+
Cream of rice	Control	12	50
	0.01% Tenox II antioxidant	21	70
	0.05% Tenox II antioxidant	22	75
Cream of barley	Control	20	80
	0.01% Tenox II antioxidant	25	175+
	0.05% Tenox II antioxidant	35	175+

Table 3, which describes the stabilization of cereals by the atomization of an emulsion as done in Experiment 3, shows that brown rice and rice bran can be stabilized by the use of an antioxidant in a water emulsion. These data indicate that the combination of BHA, BHT, propyl gallate and citric acid as found in Tenox VI antioxidant gave slightly better results than did the other combinations. For all practical purposes any of these three antioxidants could probably be used quite effectively. In this particular experiment, however, the addition of water to the cereal products should be questioned. Other experiments, which have not yet been reported, indicate that water increases the oxidation reaction and hastens the onset of rancidity. For this reason most commercial millers would probably question the use of an antioxidant emulsion in treating these cereal products.

TABLE 3
Stabilizing cereals by atomizing an emulsion of antioxidants

Product	Treatment	Average stability in days at	
		145° F.	74° F.
Brown rice	Control	13	45
Brown rice	0.025% Tenox VII antioxidant	69	200+
Brown rice	0.025% Tenox IV antioxidant	78	200+
Brown rice	0.07% Tenox VI antioxidant	77	200+
Rice bran	Control	5	42
Rice bran	0.025% Tenox VII antioxidant	17	200+
Rice bran	0.025% Tenox IV antioxidant	18	135
Rice bran	0.07% Tenox VI antioxidant	35	200+

Experiment 4 shows that a breakfast cereal can be stabilized by atomizing an oil solution of the antioxidant on a moving belt of the product. In Table 4 it may be seen that, with a control of 5 days at 145° F., the cereal sprayed with Tenox VI lasted 16 days while that in which the antioxidant was added in the liner lasted only 7 days. Where the antioxidant was applied to the cereal and to the liner the life of the cereal at 145° F. was 15 days. All treated shelf storage samples were still good when this paper was written and no results can be drawn from the room temperature storage. These data indicate, however, that in this case the addition of the antioxidant to the liner alone would not be satisfactory and when used with antioxidant treated cereal no further increase was obtained. This method of applying an antioxidant to a dry cereal appears to be the most practical from a commercial standpoint although all methods used produced a stable end product.

TABLE 4
Stabilizing precooked breakfast cereal by atomizing an oil solution of antioxidants

Treatment	Average stability in days at	
	145° F.	74° F.
Control	5	160
0.05% Tenox VI antioxidant as spray	16	200+
0.05% Tenox BHA antioxidant in liner	7	200+
0.05% Tenox VI in cereal + 0.05% Tenox BHA in liner	15	200+

SUMMARY

Samples of wheat germ meal, brown rice, rice bran, and prepared dry, precooked breakfast cereals were treated with various phenolic antioxidants. Successful stabilization was obtained through the use of these edible antioxidants. It is believed, that for commercial applications, the method wherein an antioxidant is diluted with oil and sprayed on a moving belt containing the cereal is better than any of the other methods described.

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Notes and Letters

Food Sterilization Methods—The Future

Food sterilization has been practiced systematically, and more or less scientifically, for a century and a half. During that time, sterilization has been, and today continues to be, accomplished through the agency of heat. For how long will heat continue to be the lethal agent in commercial food sterilization? It is our purpose here to analyze this prospect. We admit a bias in our viewpoint, but let us see what a biased analysis will produce.

The answer to the question just raised will be apparent after it becomes known whether or not "cold" sterilization, by means of ionizing radiation, will ever be feasible at reasonable cost. For about 15 years, intensive experimentation in this field has been under way in the United States. That is one-tenth as long as the period during which heat has been used successfully as the lethal agent in the commercial sterilization of food.

Food Sterilization—Elements of the General Problem

Heat Sterilization. Scarcely had the method of sterilizing food by heat, following its invention by Nicolas Appert, been put into use at the start of the 19th century when it was discovered that the flavor and appearance of low acid foods were impaired by the heat required to sterilize the foods. The color was darkened and the foods tasted overcooked. A way was quickly found whereby the product could be heated under steam pressure and still come out with the appearance and flavor desired—those of properly cooked food. This way was to reduce the time of heating. But—the food spoiled because it was not sterilized. It was not until more than a hundred years had elapsed that the method was found to sterilize low acid foods with heat and still retain the quality of kitchen cooked food. However, during the elapsed century, no way was found to alter the *nature* of the changes that are produced in low acid foods by heating. If foods are heat sterilized today, any resulting degradation of quality is identical in nature to that which occurred in heat sterilized foods in Appert's day—degradation resulting from reactions that appear to be primarily those of caramelization.

Only in foods containing enough sugar to enable substantial caramelization to take place while leaving enough sugar to sweeten the food, have people come to regard caramelized substances as being tasty. The flavor of caramelized nonsweet substances has never gained favor with the average person. For this reason, the history of controlled heat sterilization is replete with accounts of efforts to find a way to avoid caramelization in low acid foods during sterilization. The method, previously referred to, which is now known to accomplish this purpose is the use of an intensified dose of the lethal agent, heat, for a greatly reduced period of time, in other words, a short, high temperature, process. By means of such a process, the amount of caramelization produced is about the same as that produced in kitchen cooking—practically nil.

"Cold" Sterilization. In the intensive research work which has been in progress since about 1940 on the sterilization of food without the use of heat, the lethal agent is ionizing rays—gamma rays, cathode rays, and X-rays. The results of this work have been encouraging. It has been learned that an ionizing ray bombardment will sterilize food while creating practically no change in temperature; also that the intensity of the bombardment determines the effectiveness of the lethal action. The nature of the effect of irradiation upon cells and molecules, however, is fundamentally different from that of heat. This is shown by the fact that, to inactivate enzymes in food, an intensity of radiation is required several times as great as that required to destroy resistant bacterial spores whereas, with heat, the reverse is true. Analogously, the effect of ionizing ray bombardment upon the organoleptic quality of food differs greatly from the effect of heat treatment. The latter, as previously stated, is a browning effect accompanied by the production of a flavor of caramelization. The former possesses characteristics that elude description beyond the point of saying that the flavors created by the action of the radiation are distasteful. These flavors apparently are associated with drastic changes in molecular structure. For example, the occurrence of deamination of amino acids has been established as taking place, as well as the removal of an electron from a water molecule, giving a positive water ion.

As with heat, the magnitude of the undesirable effects of ionizing radiations varies directly as the intensity of the dose and as the length of time during which it is applied. If a way can be found to sterilize food and inactivate its enzymes without heat and without causing the deterioration of organoleptic quality which is typical of irradiation treatment, the prospects for successful use of the latter mode of food preservation will be vastly improved. By analogy, the direction of investigation which would seem to be the most promising to accomplish this result is that which was found effective in sterilization with heat; namely, to increase the dose intensity (Roentgens per minute) and reduce the time. If such a course is found to be impracticable mechanically, nonfeasible for economic or other reasons, or ineffective, the chances for success of ionizing ray sterilization appear slim indeed. Any hope of changing the *nature* of the effects of "cold" ray treatment should be abandoned at the outset. Just as the nature of the change in food quality produced by heat has never changed, the nature of the effects produced by ionizing rays will be the same forever—only the magnitude of the effects in relation to magnitude of dose stands a chance of being altered. A dose of from 10 to 20 million rep (Roentgen-equivalent-physical) is said to be required to inactivate enzymes whereas a dose of even a half million rep produces appreciable organoleptic deterioration when applied in the range of intensity used in investigations up to this time. The prospects for increasing the rate of application in Roentgens per minute and reducing the length of application suffi-

ciently to render unnoticeable the undesirable effects of an enzyme inactivating treatment do not appear bright, especially in view of the fact that it is not even known as yet whether or not an increase in intensity while keeping the rep constant will reduce the degrading effect on quality. If the enzymes are inactivated by heat, perhaps sterilization by radiation can be accomplished with a dosage of 3 million rep. This will reduce the magnitude of the problem of removing the organoleptic degradation, but, if heat is to be applied to inactivate enzymes, why not increase the intensity of the heat sufficiently to destroy the bacteria also in an application of a few seconds duration, thus accomplishing everything in one operation and emerging with a product just nicely cooked?

For foods which are eaten in cooked state, it would be disadvantageous economically to carry out a cold sterilizing operation and then have to cook the food when both operations could have been accomplished in one step by a high temperature, short time process. The fact has been well established that all foods—regardless of whether they are sterilized, pasteurized, dehydrated, cured, or fresh—deteriorate in quality when held in storage. A report published in March, 1955, by the Office of the Quartermaster General Research and Development Division, entitled *Establishing Optimum Conditions for Storage and Handling of Semi-Perishable Subsistence Items*,[a] emphatically confirms this fact. Moreover, the higher the quality of the food upon entering storage, the more rapid is its deterioration in storage. There has been no opportunity to make a storage study of raw food sterilized by ionizing radiations because no such food has been produced having a quality which would warrant such a study. Nevertheless, in view of knowledge gained by making storage studies of all other classes of preserved foods, there seems to be every reason to expect that irradiated food, if it is ever sterilized successfully, will deteriorate in storage. It appears unrealistic to expect that, among all the methods of preserving food, irradiation alone has the power to render the food incapable of quality deterioration in storage. Consequently, if food, sterilized by rays, should be produced, it will undoubtedly be advantageous, in fact, it will probably be regarded as necessary, to store it at a temperature between 32° and 36° F. in order to retard a loss of the quality which the food possesses immediately after sterilization. Low temperature in storage may be regarded as the universal preventive of organoleptic quality degradation in foods.

The Case for Heat Sterilization

This discussion, to here, is a preamble to the conclusion that heat will continue indefinitely to be the most effective and most suitable lethal agent for use in the sterilization of foods, regardless of what the future may reveal in the realm of "cold" sterilization.

Reasons:

1. The effects of heat upon organoleptic quality (carmelization effects) are less offensive to the palate than those of ionizing rays.

2. Products which have undergone the carmelizing effects of heat are known to be physiologically noninjurious.

3. Products which have undergone the decomposing effects of ionizing ray treatment are not known to be physiologically innocuous.

4. By proper choice of temperature and time of process and of the processing technic, the caramelization effects of a heat dose adequate for sterilization can be made practically nil so that the resulting sterilized product has essentially the quality of food substance freshly cooked for the table.

5. The freshly cooked quality possessed by the food immediately after heat sterilization can be preserved for any reasonable storage period—perhaps for 2 or 3 years—by storing the product at 32°-36° F.

6. In the light of the present knowledge about the perishability of foods in storage, it seems purely naive to believe that food sterilized by "cold" ray treatment would not require cold storage to preserve its quality.

7. Considering the fact that, in almost 15 years of intensive research work, no recognizable progress has been made toward preventing serious degradation of organoleptic quality by ionizing ray treatment of food, it would seem that another 15 years would be an optimistic estimate of the minimum time in which appreciable progress could possibly be made. Should this optimistic estimate prove to be sound and should some "cold" sterilized products be produced in 15 years, these products would still have to be stored under refrigeration to preserve their quality and some still would have to be cooked before they could be eaten.

It seems improbable that anyone with a comprehension of the problems associated with food storage and handling could read the Quartermaster's report of March, 1955 (*Storage and Handling*, see footnote [a]) without acquiring a conviction that it is unrealistic to store sterilized or dehydrated foods at summer temperatures. A survey of storage costs revealed that common storage, storage at 32°-36° F., and storage at 0°--15° F., respectively, have average storage and handling costs in about the ratio of 1.05 : 1.95 : 2.75. In common storage, the average cost is slightly more than 1 cent per pound per year, storage at 32°-36° F., less than 2 cents, and storage at 0°--15° F., less than 3 cents per pound per year.

Many packers feel that it is unrealistic to store canned foods under refrigeration because of the cost. One thing they seem to forget is that it costs them more than half as much to store and handle their goods in the way they do at present as it would cost if they stored under refrigeration. Knowing also that the higher the quality of a canned food when it goes into storage, the more rapid will be its deterioration in storage, a canner sometimes feels that there would be little wisdom in modifying his sterilizing process so as to retain the natural characteristics of the food unimpaired because the universal leveler, high storage temperature, will soon reduce the differences between the different grades insofar as flavor, color, and texture are concerned.

By a short, high temperature process, embodying either steam heating or some form of electrical heating

[a] Available at the Quartermaster Food and Container Institute for the Armed Forces, 1849 West Pershing Road, Chicago 9, Illinois.

(dielectric, inductive, or resistance), a sterilized packaged product can be produced having essentially the quality of kitchen cooked or of pasteurized food and this quality can be retained for many months by storage at 32°-36° F. For a risk of from 1 to 3 cents per pound of product, a canner can enable himself to deliver a product having the quality of freshly kitchen cooked food to his customers a year after the product is processed. The fact that this is possible provides the assurance that heat is *the* food sterilizing medium of the future. The handicaps of the medium, ionizing radiation, which appears to be the principal competitor of heat for this purpose, are too great to permit the enormous advantages of heat to be overcome. Even treatment by ultrasonics, a method which has not appeared to be promising and which seems to be completely in the background at present, may ultimately prove better than irradiation for food sterilization.

For a practical review of the progress achieved and of the prospects for the use of radiation sterilization, the reader is referred to an analysis recently published by *Western Canner and Packer*,[b] titled "Radiation Sterilization of Foods." For statements of views on the same subject in which many leaders in Government service, in industry, and in research are quoted, the reader is referred to a survey published in August, 1955, by The Refrigeration Research Foundation,[c] titled "Radiation of Foods—A Canvass of Facts and Opinions." In September, 1955, an appraisal guide on food irradiation, constituting a review of opinions of workers in the field, was published by *Food Processing*.[d] Considerable optimism was expressed in respect to the prospects for success of a pasteurization treatment, some optimism in respect to complete destruction of spoilage bacteria, but no optimism in respect to enzyme inactivation.

In this analysis, a discussion of the problems involved in the packaging of foods that are sterilized by ionizing rays has been purposely omitted because there are unique packaging problems associated with high temperature, short time sterilization, also. As one who has had experience in dealing with such problems, the writer ventures to express what he believes to be a conservative opinion that the packaging difficulties encountered in connection with short time heat sterilization are no greater than those that will be encountered in connection with radiation sterilization, if the latter system ever reaches the point of meeting those problems.

[b] Reprints are available at Western Canner and Packer, 121 Second St., San Francisco 5, Calif.

[c] Copies are available at the Refrigeration Research Foundation, 200 Midland Building, Colorado Springs, Colorado.

[d] Apply to *Food Processing*, 111 E. Delaware Place, Chicago 11, Illinois, for reprints.

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September 21, 1955

Sorbic Acid as a Preservative for Apple Juice

Effectiveness of sorbic acid to prevent mold and yeast spoilage in food products is becoming well known. It was hence thought that sorbic acid may have a place in the apple juice (cider) industry.

This exploratory note reports some interesting preliminary observations on the effect of sorbic acid in the preservation of apple juice at room (70° F.) temperature and at refrigerator (41° F.) temperature.

Apple juice for this study was kindly furnished by the College Cider Manufacturing Plant, Logan, Utah, and the sorbic acid by the Carbide and Carbon Chemicals Company, New York. In the cider industry, sodium benzoate is extensively used as a preservative. It was therefore included in the experiment to serve as a "yardstick" to study the effectiveness of sorbic acid. Concentrations of 0.1, 0.05, 0.025, and 0.0125% of sorbic acid and the same concentrations of sodium benzoate (Merck), on an absolute weight basis, were prepared and added to fresh apple juice. Control samples were made up and used to evaluate the respective merits of the two chemicals. One quart of juice was used to make up each sample. The experiment was conducted in triplicate. No appreciable deviation in the pH values of the juice was noticed after addition of sorbic acid or sodium benzoate.

To evaluate the effect of various concentrations of sorbic acid and of sodium benzoate on the keeping quality of apple juice at room temperature, the samples were tasted and judged by a panel of colleagues, varying from 6 to 9 members, and all well trained. A formal rating scale (1, unacceptable; 5, most desired) was used. The tests were run (a) after addition of chemicals, (b) after five days, and (c) after sixty days. The lot stored in the refrigerator at 41° F. was tasted after sixty days. The observations were conspicuously clean cut and ran definitely in favor of the sorbic acid treatments.

It was concluded on the basis of the results that sorbic acid was superior as a preservative to sodium benzoate at the concentrations and the storage levels studied. The concentrations of 0.025 and 0.0125 per cent sorbic acid did not affect the flavor of apple juice. However, at these concentrations, the taste of sodium benzoate was detectable in juice. Control samples were in a fermented condition after 5 days at room temperature and formed a turbid mud after 2 months. A slight acidic fermentation was noticed in sorbic acid as well as in sodium benzoate samples, when stored in the refrigerator.

If juice is pasteurized for a short time and a weak (0.01-0.015) concentration of sorbic acid added, the shelf life of apple juice may be increased without spoiling its characteristic flavor. Further investigation along these lines is contemplated to substantiate these exploratory observations.

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OREGON, No. 16: Chairman, E. W. Harvey. Secretary, Curtis J. Wilder, Food Technology Dept., Oregon State College, Corvallis, Ore. Councilor, C. L. Beardsley.

DIXIE, No. 17: Chairman, J. G. Woodroof. Secretary, Carroll F. Neff, 193 Princeton Way, N. E., Atlanta 6, Georgia. Councilor, J. O. Mundt.

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INDIANA, No. 20: Chairman, S. E. Hartsell. Secretary, Verna McCallum, 941 N. Meridian, Indianapolis 6, Ind. Councilor, N. W. Desrosier.

PITTSBURGH, No. 21: Chairman, C. J. Steinicke. Secretary, John L. Secrist, H. J. Heinz Co., Food Research Dept., Pittsburgh 30, Pa. Councilor, H. L. Lang.

BRITISH COLUMBIA, No. 22: Chairman, D. H. Dougans. Secretary, William E. Pearson, Lucky Lager Brewing Co., 210 Brunette St., New Westminster, B. C., Canada. Councilor, I. F. Greenwood.

AUSTRALIA SOUTHERN, No. 23: Chairman, J. E. Rice. Secretary, Kevin B. Smith, Southern Can Co. Pty. Ltd., 240 Geelong Road, West Footscray, W-11, Victoria, Australia. Councilor, M. K. Paxton.

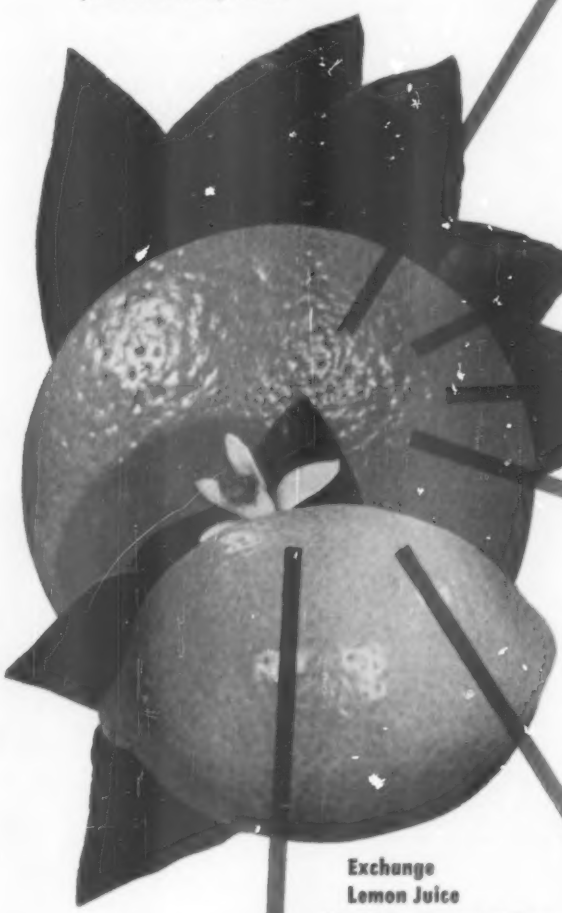
AK-SAR-BEN, No. 24: Chairman, G. C. Kolb, Jr. Secretary, Harriet L. Paige, C. A. Swanson & Sons, 1202 Douglas, Omaha 8, Nebr. Councilor, I. L. Ressler.

MEMBERSHIP

Write to nearest regional secretary, if within an area covered by a regional section, or to the Executive Secretary of the Institute for an application form and information regarding qualifications and classifications.

Look to Sunkist
for progressive research in food processing

Yes, in every field of food processing, the Sunkist Growers laboratories are making ever-widening contributions to the increased quality of food products. Here are some typical Exchange Brand product developments.



Exchange Oil of Orange

Always consistent, always outstanding in flavor, strength and aroma. An essence you can rely on. Made from fruit grown in the famous Sunkist groves of California.

Exchange Oil of Lemon

The 4-to-1 favorite over all other lemon oils combined! The reason is the superior flavor that comes only from California-grown lemons processed by exacting Sunkist standards.

Exchange Preserver's Pectin

Here is *ever* jell strength that gives you consistent, complete reliability in setting control.

Exchange Low Methoxyl Pectin

A natural fruit pectin that jells without sugar. Completely tasteless, permitting the use of the most delicate flavors. Pies made with Exchange Low Methoxyl Pectin won't "run" or "weep" when cut—and you have never tasted such natural juicy fruit flavor. Famous too for aspics, jellied fruit or vegetable salads, dietetic preserves or non-sugar jells.

Exchange Lemon Juice

Nothing can match lemon juice for bringing out the natural flavor of *any* food product. It's a superior acidulant in the preparation of mayonnaise, fruit cocktail, figs, fruit nectar, prunes and other heavy-syrup products. Highly effective as an anti-oxidant in processing frozen foods. Citric acid molecules have also been established as effective in the retarding of mold growth. Available in concentrated or single strength form.

Sunkist Growers

Exchange ®

PRODUCTS DEPARTMENT • ONTARIO, CALIFORNIA
400 W. Madison Street, Chicago 6, Illinois
99 Hudson Street, New York 13, N. Y.
318 Elm Street, Dallas 2, Texas

. . . ***in the public interest***

Automation must play a larger role in industry if Americans are to keep on raising their living standards and gaining leisure hours, according to Mr. Henry F. Dever, president of Brown Instruments Division of Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia. He cited productivity per-worker figures in relation to the required "gross national product," pointing out that by 1975, in the opinion of experts, our "GNP" will have to be around $858 billion if our standard of living is to continue the rate of rise of the past 15 years. To achieve this output while also enjoying the leisure time of a 32-hour week, he pointed out, automation or something as good, for raising individual productivity, will have to be part of the scheme of things. The instrument manufacturer cited 4 "built-in governors" which help control the pace at which industry can progress toward full automation: (1) availability of equipment; (2) the considerable expense of engineering and research needed to produce it, followed by solution of educational and adaptation problems; (3) need for flexible design, since every plant, process, or manufacturing operation presents unique and individual problems; and (4) the very real need to be aware of the sociological implications and to move slowly, with care and advance planning.

◆ ◆ ◆

To meet increasing industry need for continued safety programs and practices, a new home study course in Industrial Safety Engineering has been added to the curriculum of International Correspondence Schools, Scranton 9, Pa., according to Mr. John C. Villaume, dean of the faculty. It is pointed out that industry's annual accident toll both on and off the job amounts to 48,000 worker fatalities, more than 85,000 permanent disablements, and an additional 4,350 000 non-fatal injuries. The Course is designed to help industrial supervisors in charge of safety, industrial engineers who desire safety training, safety representatives of labor departments, and those whose responsibilities call for a knowledge of safety practices. Comprised of 41 lessons requiring an estimated average study time of 650 hours, the Course provides instruction in mathematics, machine sketching, blueprint reading, industrial psychology, handling of materials, plant and production equipment layout, and safety principles and practices. It has been made available on the I.C.S. Selective Plan which permits employers to select only those instructional units which meet an immediate and specific need.

◆ ◆ ◆

In response to an emergency appeal from the American Red Cross, the Chas. Pfizer & Co., Inc., plant at Groton, Conn., launched a unique company-employee helping hand campaign to raise funds for the victims of the flood-devastated Connecticut and adjacent areas. More than $5,000 was raised in a program in which the company donated $2.00 for every $1.00 employee contribution. Nearly all of the plant's 1,170 employees contributed. At the height of the disaster, a $50,000 supply of antibiotics and other drugs was dispatched by Pfizer into the flood areas of Connecticut and adjacent states, and to Allentown, Pa. These free-of-charge drugs replaced drug store stocks damaged by water.

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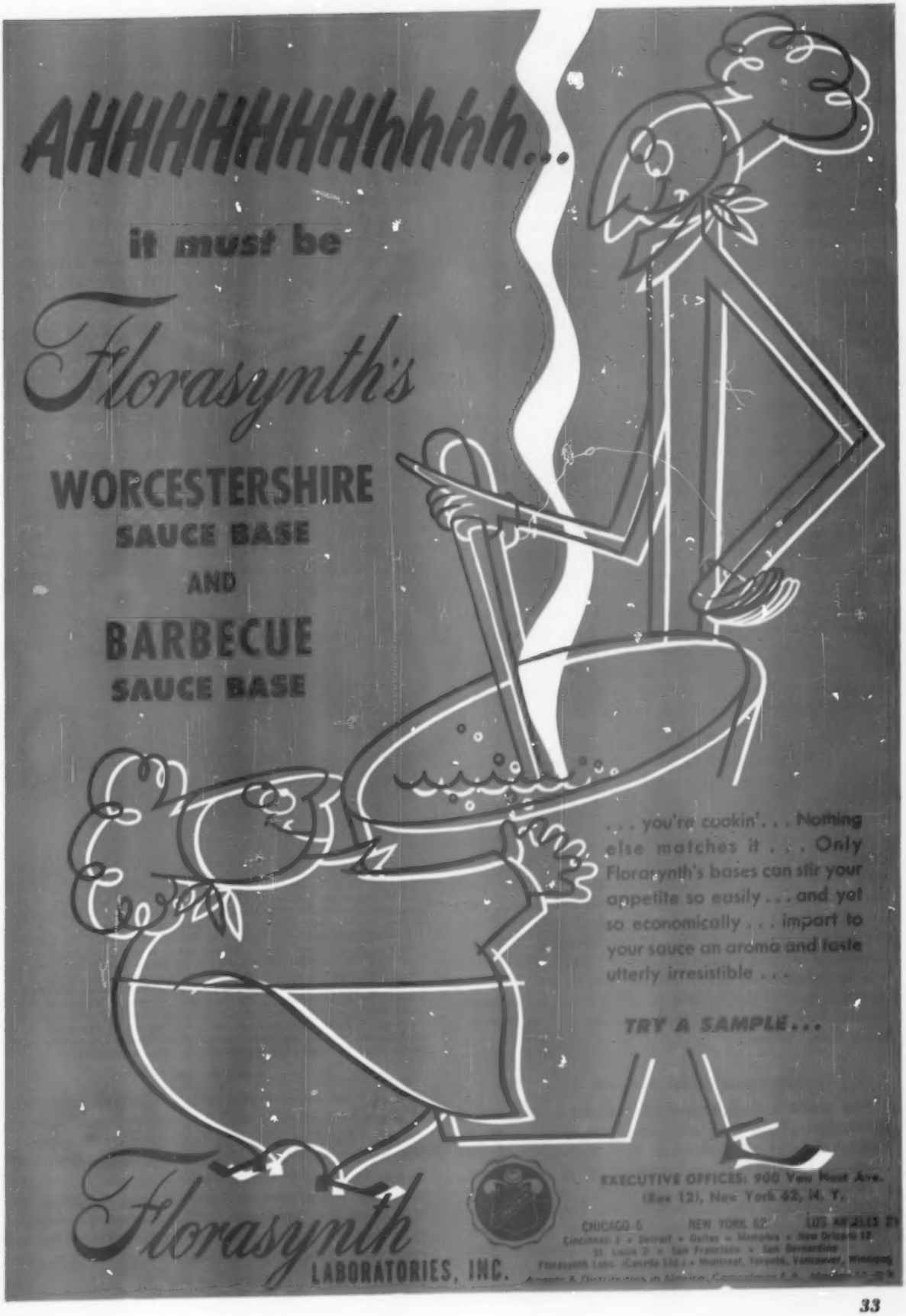
Dr. C. B. Miles of Westfield, left, research director for the Westvaco Mineral Products Division of Food Machinery and Chemical Corporation, presents a check for $7,500 to Dr. Lewis Webster Jones, right, president of Rutgers University, to support a study of high polymer phosphates in the School of Chemistry. Dr. Peter A. van der Meulen, director of the school, looks on.

◆ ◆ ◆

Some of the electrical problems in food processing plants, stemming from the peculiar nature of the business, were pointed out recently by Mr. R. S. Wilson, electrical engineer for the California Packing Corp., San Francisco. "Water, chemicals, steam, and acids create hazardous conditions, damaging electrical machinery, which in turn may become dangerous to employees. Dangerous practices, such as ignoring safety precautions, defeating safety devices, and improper clearance of power lines also contribute to hazardous conditions," he stated. Mr. Wilson advocated use of the "buddy system"—the habit of working with someone nearby who can be of assistance in case of trouble —for those working on electrical machinery.

(Continued on page 34)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. . . you're cookin'. . . Nothing else matches it . . . Only Florasynth's bases can stir your appetite so easily . . . and yet so economically . . . impart to your sauce an aroma and taste utterly irresistible . . .
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Florasynth Labs. (Canada Ltd.) • Montreal, Toronto, Vancouver, Winnipeg

FOOD INDUSTRY TOPICS

(Continued from page 32)

For the 16th consecutive year, net sales of International Minerals & Chemical Corp., 20 N. Wacker Dr., Chicago, have increased over the preceeding year, according to the annual report for fiscal year ended June 30, 1955. Net sales were $96,485,017—highest in International's history, and 3.1% higher than sales for the preceding fiscal year. Net earnings were $6,321,903, compared with $6,043,979 for fiscal 1954. This was equivalent to $2.55 per share of common stock outstanding, compared with $2.44. Earnings before income taxes amounted to $7,396,903, compared with $7,113,979 for the preceding year. According to Mr. Louis Ware, president, the higher sales volume was realized because of the sale of additional products manufactured in new facilities.

◆ ◆ ◆

Announcement that additional copies of the 16-mm. sound color movie, "The Operation and Application of Turbo-Dryers," are now available for engineering groups, societies, private company showings, and university classrooms or lecture halls was made by Wyssmont Co., Inc., 42-05 27th St., Long Island City 1, N. Y. The 12-minute film thoroughly explains drying in general, with particular emphasis on the design, operation, and uses of vertical Turbo-Dryers in the food, pigment, coal, fertilizer, chemical process, and related industries. Emphasis is placed on the method of drying heat- or oxygen-sensitive materials. Call or write giving dates required and complete delivery instructions. Delivery and pickup is via Western Union, with all charges prepaid.

◆ ◆ ◆

Public Service Awards for their "contribution to the National Defense through participation in the Civil Defense Atomic Test Program, AEC Nevada Test Site, Spring, 1955" have been presented to the Paul F. Beich Co., Bloomington, Ill., and the National Confectioners' Assn. Through NCA, arrangements were made to have ration confections included in the mass feeding program during "Operation Cue," the Civil Defense Atomic Test Program held last April at the AEC Nevada Test Site, which involved feeding thousands of participants. Paul F. Beich Company was manufacturing ration confections on government contract, and at the request of NCA made up several thousand additional units for inclusion in the "Operation Cue" menu.

. . . *things new under the sun*

The world's first successful industrial ultrasonic flowmeter—which accurately measures either mass or volume flow of virtually any fluid regardless of its electrical conductivity and without being affected by accompanying variables — has been introduced by Fischer & Porter Co., Hatboro 35, Pa. Design is based upon the exceptionally rigid requirements for measuring in-flight refueling flow rates for aircraft. The pressure drop of the new flowmeter is practically zero. Built into a short pipe section, it has no restrictions or moving parts to obstruct flow or cause clogging. Present designs have a capacity up to 12,000 pounds per minute with a fluid density range of approximately 2.5 to 1. It can be adapted to any standard pipe size down to 2-inch. Temperature limit is minus 50° to plus 225° F. standard, and up to 750° F. with special provisions. The pressure limit is 150 and 300 psi standard, but it can be adapted to higher pressures. The flowmeter is made from metals to meet corrosion resistance requirements. Fischer & Porter will manufacture the item for industrial applications under license from The W. L. Maxson Corp., New York, N. Y.

◆ ◆ ◆

Tube Turns Plastics, Inc., 224 E. Broadway, Louisville, Ky., has introduced a **new line of instrumentation fittings made of unplasticized polyvinyl chloride** and, for use with them, **corrosion resistant flexible tubing.** Because of remarkable corrosion resistant qualities, strength, and low cost, the fittings and tubing can be employed advantageously in the instrumentation of chemical plants, hospitals, experimental laboratories, and in the food, drug, and beverage processing industries. Furnished in both ¼" and ⅜" sizes, they permit an entire assembly to be put together by hand without aid of wrenches, flaring or bending tools, or stretchers. No sleeves or ferrules are involved.

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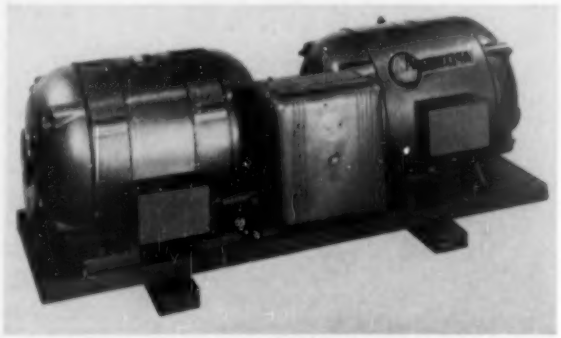

The ultrasonic barrier to chemical, food, drug, petroleum, plastic, paper, rubber, textile, and paint processing has been broken by introduction of low-cost, high-frequency rotating generators such as this 5 kilowatt unit, manufactured by Acoustica Associates, Inc., Glenwood Landing, Long Island, N. Y. Others range in size from 2 kw. to 150 kw. These alternators are capable of supplying economical power for energizing multiple arrays of above audible sound generating transducers needed to irradiate materials and products being produced en masse. As a consequence, the favorable results of laboratory ultrasonic experimentation now can be extended into full scale plant production. Naturally, dimensions, type, and ultrasonic character of the transducers, as well as their critical disposition in processing equipment, must be engineered specifically for each application.

◆ ◆ ◆

A new one-coat vinyl plastic all-purpose paint, suitable for both interior and exterior applications, is announced by The Wooster Sealkote Co., Wooster, O. Known as "Seal-Kote" (T. M. Registered), the ready-to-use liquid paint can be applied on either wet or dry surfaces. When used on damp masonry, inside or out, it reportedly prevents further water penetration. However, it is so formulated as to permit free and constant "breathing" through its plastic film, thus

(Continued on page 36)

THE THREE P's IN SPISORAMA PEPPER ARE

PURITY PREDICTABILITY POTENCY

Like any foundation, a basic seasoning such as pepper must be a skillful composite of the finest materials and artistic craftsmanship. SPISORAMA dry soluble PEPPER is a premium product, made from pure oleoresin black pepper decolorized and standardized at a level of ultimate quality. All the bite, all the time-honored flavor of the world's finest Black Pepper are captured in this product, and made instantly available for maximum utilization in dry soluble form. Absolute freedom from specking is guaranteed, as are maximum purity, potency and predictability. Exacting standards of manufacture, and the use of all stainless steel equipment are our own best assets and our safeguards to you. Trial quantities on request.

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ESSENTIAL OILS • AROMATIC CHEMICALS • PERFUME BASES • FLAVOR BASES • DRY SOLUBLE SEASONINGS

FOOD INDUSTRY TOPICS

(Continued from page 34)

releasing all internal moisture. Recommended for use on cement and cinder blocks, concrete, brick, wood, plaster, wallboard, Celotex, stucco, masonry, and even wallpaper. Resists mild industrial acids, alkalis, grease, oil, fats, and dirt. It does not bleed or discolor when applied over asphalt. Available in 8 colors, white, and clear, and in one-gallon cans, 5-gallon pails, and 30- and 55-gallon drums.

◆ ◆ ◆

A secondary air damper now is incorporated in the blower housing of all Cyclotherm Steam Generators, from 18 to 60 hp. With its inclusion on these boilers, the entire line ranging from 18 to 500 hp is furnished with this equipment, making it simpler and easier to adjust the secondary air requirements of the boiler. The new damper can be adjusted more quickly than the old arrangement of adjusting blower vanes, and also gives greater accuracy in adjustment, resulting in higher combusion efficiency. Write Cyclotherm Division, National-U. S. Radiator Corp., Oswego, N. Y.

◆ ◆ ◆

A new Corrosion Test Humidity Cabinet for JAN-H-792, announced by Labline, Inc., 3070 W. Grand Ave., Chicago 22, Ill., tests effectiveness of corrosion preventive materials. The Cabinet operates at 120° F., and is approximately 28″ x 28″ x 28″, with immersion heaters, air manifold with diffusers, and revolving rack rotating at 1/3 rpm holding 33 test panels. Cover is airplane cloth to permit exhausting of air while retaining humidity in chamber. Dual thermostat provides complete safety. Interior of chamber is tinned copper; exterior is special marine plywood, finished in Sand-Tan enamel. Unit may be used also for all other types of humidity and temperature tests. Write for Bulletin 3910.

◆ ◆ ◆

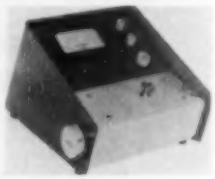
Lamicor, the heavy-duty fiberglass specially developed for the food industry, now comes in sizes up to 9 feet in length. Easy to clean or sterilize, and available in a wide color range including white, Lamicor resists penetration by most acids and alkalis, and does not absorb odors emitted by animal juices, grease, or other stale deposits. Bearing unusual insulating properties, Lamicor will not warp or swell when exposed to temperature extremes. Impervious to action by rodents, mildew, or moisture, and will not corrode. Write Strick Plastics Corp., 31-06 38th Ave., Long Island City, N. Y.

◆ ◆ ◆

A portable sprayer for such solutions as insecticides, fumigants, emulsions, deodorizing liquids, oils, polishes, floor dressings, moth proofers, and glass cleaners is available from Spraying Systems Co., 3201 Randolph St., Bellwood, Ill. The No. 6000 sprayer weighs only 1¾ pounds and can be operated with one hand. Supplied complete with unbreakable plastic jar, the unit has no moving parts to wear. Interchangeable nozzle set-ups are available to produce a wide variety of sprays. Capacity is regulated by selection of set-up and by varying air pressure. A companion unit, No. 5870 chlorine sprayer, is identical to No. 6000, except that all metal parts that come in contact with chlorine solutions are made of stainless steel. Write for Bulletin 76 for information on both units.

◆ ◆ ◆

A sugar colorimeter for specification of sugar whiteness now is available. Designed by Beckman Instruments, Inc., Fullerton 1, Calif., in close cooperation with the sugar industry, it follows the tentative method adopted by the U. S. Nat'l Committee on Sugar Analysis as well as the International Commission for Uniform Methods of Sugar Analysis. The Beckman Sugar Colorimeter provides a quick and accurate way to describe sugar whiteness so that everyone using it can obtain color index numbers which are directly comparable. Write the firm's Beckman Division and request Data File 427.



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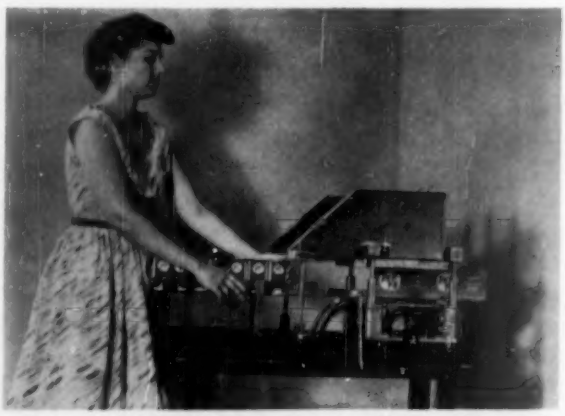

A new hand packager for test runs and promotional sales in multi-unit cartons is offered by Atlanta Paper Co., originators of the famous Cluster-Pak automatic multi-unit cartoner and carton. The Cluster-Pak "Midget" Hand Packager was developed to meet needs of the food and grocery products industry for short runs, test packaging requirements, and promotional sales. It can package from 7 to 10 cartons per minute, and will carton 5- to 12-ounce cans in single rows of 2 to 6 cans, or double rows of 4 to 12 cans. The machine uses Atlanta Paper Company's Cluster-Pak carton—a self-locking carton requiring no glue or staples. Selling for under $1,000, the unit occupies 3 square feet of floor space and stands 52 inches high. Write the firm c/o Mitchell WerBell, 926 Peachtree St., Atlanta, Ga.

◆ ◆ ◆

Designed to combat flooded floors, standing water on flat roofs, and for emergency use in a lightweight portable pump built by Hypro Engineering, Inc., 700 39th Ave. N. E., Minneapolis 21, Minn. Weighing only 26 pounds complete with motor, hinged carrying han-

(Continued on page 38)

You're sure to be in

GOOD TASTE

when you specify

UNGERER

IMITATION CUSTARD No. 255

Another top quality product of the Ungerer laboratories. Samples and technical information on the use of this flavor in your product will be supplied on request.

Plant and Laboratories, Totowa, New Jersey

Ungerer & Co.

161 Avenue of the Americas, New York 13, N. Y.

CHICAGO • BOSTON • PHILADELPHIA • ST. LOUIS • LOS ANGELES • ATLANTA

FOOD INDUSTRY TOPICS

(Continued from page 36)

dle, and vacuum switch that permits untended operation, the Hypro Portable has a capacity of up to 5 gallons per minute with pressures up to 30 pounds. The pump will lift either clean or dirty water up to 10 feet unprimed or 22 feet primed, and has outside threaded ports for standard female garden hose couplings. Write Dept. KP.

◆ ◆ ◆

A new Milton Roy Controlled Volume Pump with instrument air stroke length adjustment solves specific low capacity flow control problems in connection with pneumatic process control systems. The unit utilizes a unique air servo system with feedback loop to give capacity adjustment with accuracy within one percent. Sensitivity is such that 1/70 psi change in instrument control air pressure causes re-setting of pump stroke length. Details from Milton Roy Co., Station N, 1300 E. Mermaid Lane, Philadelphia 18, Pa.

◆ ◆

An improved sliding metal handle for fruit and vegetable cartons, available from Crown Cork & Seal Co., makes for easier stacking and carrying of produce by dealers and store operators. Handle and box, shipped separately, are assembled quickly. The handle hooks into special openings in the outer wall of a double-walled box. When not in use, the metal handle slides down into the box until its top is flush with box top. As much as 80 pounds can be lifted safely—more than 8 times normal carton weight. Because it eliminates need for stitching operators and machinery, the metal handle costs no more than ordinary wooden handles. Matching corrugated boxes available in standard 8- and 12-quart sizes. Handles can be made to fit any width of box. Write the firm c/o Arthur L. Greene, 152 W. 42nd St., New York 36, N. Y.

◆ ◆ ◆

Magnuson Color Comparators, made of plastic, recently were adopted as the official standard for determining color in grading lima beans by the U. S. Department of Agriculture. Write Magnuson Engineers, 509 Emory St., San Jose 10, Calif.

◆ ◆ ◆

High load-handling capacity, low control current, new stable DC circuitry, and a 4-way panel selector switch that permits "fail safe" operations of the system in any application are features of the new LaPine electronic relay manufactured by Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 29, Ill. The relay has a capacity of 20 amps at 120 volts AC for handling high-wattage loads such as laboratory water-bath heat-

(Continued on page 40)

Is a link missing in your Quality Control Chain?

But he can *be prepared* in advance to spot the trouble *the moment it occurs* by using

cook-chex

No Food Technologist can tell *in advance* when a batch is going to "go bad."

...MPERATURE SPECIFICATIONS FOR FREE COOK-...ATORS CUSTOM-MADE TO FIT YOUR REQUIREMENTS

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Without obligation, please send me a supply of COOK-CHEX indicator tags designed for use at _____ degrees F., for _____ minutes.

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Makers of salad dressing need '999'

So do makers and processors of beer . . . candy . . . canned foods . . . cereals . . . malted milk . . . margarine . . . mayonnaise . . . meats . . . olives . . . sauerkraut . . .

Morton '999' Salt
for better flavor and quality

Morton '999' Salt insures uniform flavor and quality in processed foods for two reasons:

1. Morton '999' is *guaranteed* always to contain more than 99.9% pure sodium chloride. The remaining 0.1% (or less) is a neutral inert sodium salt—and never bitter calcium or magnesium compounds.

2. Morton '999' Salt is produced by vacuum pan evaporation to assure you a salt that is clean, free-flowing... evenly soluble. '999' Salt is particularly low in objectionable trace metals.

For more information about Morton '999' Salt—and about Morton service and technical help—write this week to:

MORTON SALT COMPANY

Industrial Division, Department T7-11
120 South La Salle Street, Chicago 3, Illinois

FOOD INDUSTRY TOPICS

(Continued from page 38)

ers. Sensitivity of the relay enables it to be actuated by low-current sensing elements such as mercury-column thermoregulators or directly by a Type 930 gas phototube. Designed to eliminate shock hazard when used for water-bath operation.

◆ ◆ ◆

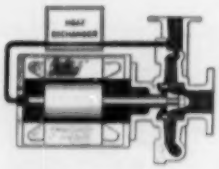
Used for filtering molasses, foods, antibiotics, vegetable oils, paints, pigments, coolant oils, viscose, and acetate, VISKON nonwoven filter fabric is made of rayon or cotton fibers bonded together by cellulose, resins, or elastomers. It gives a high flow rate with good particle retention, and particles cannot become imbedded. It is stronger than paper and is insoluble in all common organic and inorganic solvents. Chemically pure and non-toxic, it is produced in a wide variety of weights and can be custom-made to specification. Write the Fabrics Division of The Visking Corp., North Little Rock, Ark., or 400 W. Madison St., Chicago, Ill.

◆ ◆ ◆

An increase in filling operations from 30% to 40%, plus a decrease in packaging time from 6 hours to one hour have been announced by Lucier's Salad Co., Daly City, Calif., with the recent installation of Simplex Filler Table Model A. This semi-automatic filler with a 20-gallon stainless cone hopper, fills 2000 to 2500 pounds of salads per day in one-pound plastic and paper containers. The single piston filler is made of acid-resistant contact parts, and has a dismantling time for cleaning of under 5 minutes. Designed for space-saving areas, it fills liquids and semi-solids. Write F. L. Burt Co., 571 Seventh St., San Francisco, Calif.

◆ ◆ ◆

Combining an integral heat exchanger with a special high-temperature pump design, the newest addition to the line of leak-proof "canned motor" Chempumps is ideal for handling fluids at temperatures as high as 1000° F. Two Chempump model series have the "necked down" design for high temperature work. Model CHS pumps are available in 5 and 7½ hp sizes, and Model CFT units in ¾ and 1½ hp sizes. Maximum head developed is 195 feet, and maximum capacity is 250 gpm. Write Chempump Corp., Station I, 1300 E. Mermaid Lane, Philadelphia 18, Pa.



◆ ◆ ◆

A radical new torsion testing machine which employs an SR-4 resistance wire strain gauge device for electrical measurement of torsion has been produced by Baldwin-Lima-Hamilton Corp. The machine is of 60,000 in.-lb. capacity, and accommodates test specimens having a maximum length of 6 feet between chucks. It has a reversible drive with an infinitely variable speed range of 5 to 200 degrees per minute. Response to load changes is fast: up to full dial in one second. Faster response is obtainable with oscillograph or oscilloscope. A load-torque recorder can be used with the machine also. Write c/o Ketchum, MacLeod & Grove, Inc., 411 Seventh Ave., Pittsburgh 19, Pa.

◆ ◆ ◆

A new line of "Teflon" flexible tubing that is chemically inert, allows no contamination in high purity streams, and is unaffected by corrosive fluids and strong solvents is available from Pennsylvania Fluoroplastics Co., 1115 N. 38th St., Philadelphia 4, Pa. The tubing has a service temperature range from that of liquid oxygen up to 500° F., and is ideal for chemical lines requiring vacuum or medium and low pressures. Standard wall thickness is 30 mils for inside diameters ranging from ⅛" to one inch. Larger tubes have heavier walls, and thicker or thinner walls are available. Tubing supplied in all colors for identification of fluid streams. Ferrule type fittings made from Monel, nickel, stainless steel, and nylon can be used with the tubing, or "Teflon" fittings can be used where fluids should contact only "Teflon" because of chemical attack or contamination.

◆ ◆ ◆

A catalytic wire element that can banish oven odors, air-borne bacteria, or tobacco smoke has been developed by Oxy-Catalyst, Inc. The device, to be known as the Oxycoil, consists basically of turns of thin wire coated with a remarkable catalytic agent. When heated by electric current, the Oxycoil burns any organic combustible present in a stream of air. The unit makes use of the basic principle successfully applied by Oxy-Catalyst to elimination of industrial stack pollutants and combustion engine exhaust fumes. Write the firm c/o Gray & Rogers, Advertising, 12 S. Twelfth St., Philadelphia 7, Pa.

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The "ready-mix" standard solutions called "Stansols," manufactured by Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago 22, Ill., are guaranteed for accuracy within one part in 1000, and are standardized 5 times before packaging. They are used as reference solutions for testing chemical formulas. Claims for accuracy are based on 2 factors: (1) the same burette is used for standardizing the stock solution and dispensing the solution into the ampules; and (2) a burette of 100 ml. volume, which has a fine graduate stem reading to 0.05 ml. so that it can be read to one part in 2000, is employed.

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A laboratory balance that combines large capacity with high sensitivity is offered by The Torsion Balance Co. Model HT-1 has an S. R. of 0.75 grams (0.75 grams causes the pointer to deflect 2 index divisions), and capacity of 14 kg. Two slide weights on a single

beam permit weighings from one gram to 1000 grams without use of loose weights. Net weight is 39 pounds; shipping weight 60 pounds.

◆ ◆ ◆

Processed and standardized specifically for chromatographic use, a **series of analytical-grade adsorption aluminas** are offered by Bio-Rad Laboratories, 800 Delaware St., Berkeley, Calif. Available are standardized acid, basic, and neutral materials of activity grade I (Brockmann).

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Removal of undesirable magnetic particles in processing foods and chemicals is made easy with an Ohio Super Magnetomotive Magnet, manufactured by The Ohio Electric Mfg. Co., 5400 Dunham Rd., Maple Heights, Cleveland, O. The rectangular field of the magnets is designed for suspension over the head pulley or in a horizontal position over a conveyor belt, suspended by adjustable length cables. Class B insulating materials are used throughout to withstand high temperatures encountered under continuous operation. Models vary from Model SM20, with an effective range of 6 inches at a belt speed of approximately 200 feet per minute, up to Model SM60, with an effective range of 19 inches at a belt speed of approximately 500 feet per minute.

◆ ◆ ◆

Radiant heat work temperatures up to 600° F. are supplied by a **new waterproof and rustproof electric Radiant Panel** for food processing requirements such as ham, bacon, and sausage smoking, and other applications where periodic washdowns are mandatory. Each panel, measuring 9½ feet long by 37½ inches high, is constructed of aluminum and Monel with six ⅜" diameter, waterproof, immersion type, tubular heating elements. Design flexibility and ruggedness permit easy assembly of units into side or overhead tunnel mounting, from the smallest to completely mechanized conveyor installations. Work temperatures are controlled by speed of conveyor, distance from panel, and adjustment of element temperature through a manually set, automatic electric input timer. Temperature of Radiant Panel remains constant for any given setting. Automatic controls available to suit number of units required. Marketed under trade name "Chromalox," catalog number RPK-390, and manufactured by Edwin L. Wiegand Co., 7500 Thomas Blvd., Pittsburgh 8, Pa.

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A new safety device for inserting glass tubes in rubber stoppers, rubber tubing, and bulbs, the Cenco "Tube-On" Safety Tube Inserter, is said to virtually eliminate danger of lacerated fingers or hands when a glass tube is inserted. In addition, the "Tube-On" sleeves most laboratory tubing in seconds—including T-tubes, L-tubes, and Y-tubes. Adaptable to angle tubing of 1.4 mm. to 9 mm. in diameter, and up to 13 mm. or more for straight tubing. Price of the

the greatest advance in meat seasoning

Scientifically manufactured MAGNA SPICE CONCENTROLS have modernized the seasoning of meats by making available the true flavor components of herbs and spices in the most concentrated form known to Science . . . yet easily processed in your own plant. All the flavor is released immediately. Each batch of your product is uniformly and identically seasoned.

- Out perform crude herbs and spices.
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Write for the new MM&R booklet — "The Greatest Advance in Meat Seasoning."

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FOOD INDUSTRY TOPICS

"Tube-On," Cenco catalog number 13993, is $10 each, $9 in lots of 3, $8 in lots of 6, and $7.50 in lots of 12.

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The Abbeon Supply Co., 179-25 Jamaica Ave., Jamaica 32, N. Y., announces **a new direct reading humidity and temperature indicator** called the Model 187 Hygrodial. The instrument is uniformly accurate over the entire RH range. Temperature scale is 1½ inches high and covers a range of 0° to 110° F. Accurate to within one degree at 70° F., and to within 3° at the extremes of the scale. Over-all dimensions are 6" long by 4" high by $2\frac{17}{32}$" deep. The price is $9.95.

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The new SABRO portable laboratory for quantitative bacteria analysis of water is announced by Salem-Brosius, Inc. Designed for field use, it makes possible complete analysis in about 18 hours, instead of the 2 to 4 days required for conventional testing procedures. The SABRO test employs the membrane filter technique, wherein a quantity of water is passed through a circular membrane filter. Technicians can be trained to perform the analysis quickly, and normal sanitation measures are sufficient for accurate test data. The SABRO kit is slightly larger than a portable typewriter case and contains all equipment essential to the test not available normally in the field. Address the firm c/o Bond & Starr, 337 Boulevard of Allies, Pittsburgh 22, Pa.

◆ ◆ ◆

To protect and greatly reduce exterior wear from contact with rough and abrasive surfaces, Flexaust hoses and Portovent retractable ducts made of coated fabrics and spiral wire reinforcement are now available with an added Vinyl Wearstrip which is fully bonded over the spiral wire reinforcement and where the hose is exposed most to damage. In addition to assuring longer service life, it affords possibilities for using lightweight hose in applications hitherto considered too severe. Available for Flexaust hoses in 4 through 12-inch i.d., and Portovent retractable ducts in sizes 3- through 36-inch i.d. Write The Flexaust Co., 100 Park Ave., New York 17, N. Y.

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To separate egg yolk colors into 2 classifications, according to Neppeo standards, with adjustability between the 2 colors according to specific requirements, Librascope Inc., Glendale, Calif., offers a production tool called the Librascope Color Discriminator. Intended for use with automatic egg-breaking and separating machines to automatically discriminate between colors of egg yolks at rates exceeding 125 per minute, it is said to have been 98% accurate in test commercial runs. The 11½" by 4½" by 10" electronic device incorporates its own light source, automatic voltage regulation, filtering system, photoelectric pickup, and amplifying features. Available through Food Systems, Inc., 6083 Estates Dr., Oakland 11, Calif.

. . . *the literary corner*

Two new pieces of technical literature from American Optical Co. One, a 12-page brochure, is entitled "AO Introduces the Bush-Duryee-Hastings Micromanipulator." The instrument is described as the ultimate for micrurgical studies at all magnifications, combining unsurpassed precision with convenience. The second item, also 12 pages, is devoted to the AO Rapid Scanning Spectrophotometer. A price list insert is included. Obtainable from Instrument Division, American Optical Co., Box A, Buffalo 15, N. Y., or contact the AO branch office in principal cities.

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"Banana Flavors" and "Flavor Meters," the latter an erudite little article on sensory testing panels, are featured articles in the No. 4, 1955, issue of *The Givaudan Flavorist*, published by Givaudan Flavors, Inc., 330 W. 42nd St., New York 36, N. Y.

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"Seven out of 10 buying decisions on all supermarket products are made after shoppers enter stores . . . nearly half of all supermarket products are bought on impulse . . . 2 out of 3 shoppers make up their minds without a shopping list . . . the average shopper spends little more than a minute in buying each item . . . 'Momma' still does most of the shopping." These

facts are brought out in a master shopping study listing in-store buying decision rates for supermarket products in 88 different classifications. Entitled "Master Summary, Latest Facts About Today's Shopper in Supermarkets," the 12-page brochure is obtainable from Film Dept., E. I. du Pont de Nemours & Co., Wilmington 98, Del.

The same firm's Pigments Department offers a new booklet giving up-to-date data on the properties of titanium and discussing methods of fabricating the lightweight metal. Address as above.

• • •

A 12-page catalog released by Falls Industries, Inc., 31883 Aurora Rd., Solon, O., covers the operating and dimensional specifications of IMPERVITE (resin impregnated graphite), as well as diaphragm and custom-designed valves. For comparative purposes, physical properties are charted for graphite, IMPERVITE, and GRAPH-I-TITE (carbon-impregnated graphite). A section entitled "Methods of Connection" gives detailed instructions on how to cut threads and serrate and cement pipe in the field, using portable tools.

• • •

A new 8-page technical bulletin outlines the qualities of Sorbic as a selective food fungistat. Sorbic, the food grade of sorbic acid (not to be confused with ascorbic acid), is produced by Carbide and Carbon Chemicals Co., Division of Union Carbide and Carbon Corp., 30 E. 42nd St., New York 17, N. Y. In addition to its being used to protect cheeses, baked goods, salads, and citrus products, it reportedly shows promise in pickles, sirups, tomato products, and many other foods.

• • •

According to *Industrial Research Newsletter* for September 1955, published by Armour Research Foundation of Illinois Institute of Technology, Technology Center, Chicago 16, Ill., a new centrifuge has been developed by Eastman Kodak to clarify gelatin. The instrument removes essentially all floating and settling solids, dissolved air, and foam. Cleansed solutions are said to be free from degradation by bacterial attack.

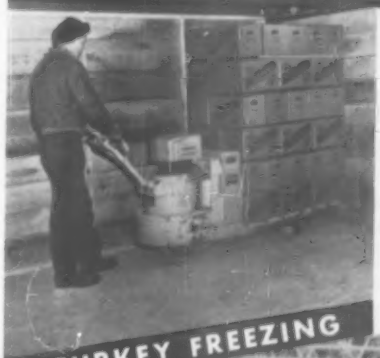
• • •

Reprints of an article which appeared in the January-February, 1955, issue of *Food Research* may be obtained without cost from Southern Regional Research Laboratory, 2100 Robert E. Lee Blvd., New Orleans 19, La. The article describes how workers at the SRRL made and applied color references in grading experimental packs of dehydrated sweet potatoes. The idea reportedly has potential application to other agricultural products.

• • •

A new, 12-page bulletin describing the company's line of 6" strip-chart recorders for pressure, liquid level, temperature, flow, and mechanical motion, and a 16-page bulletin (Q1305) consisting of a new price list and specifications on their pH recorders and controllers for use with Beckman electrodes and amplifiers have been issued by The Bristol Co., Waterbury 20, Conn.

NIAGARA "NO FROST" *for* Always Clean Food Freezing and Storage Rooms



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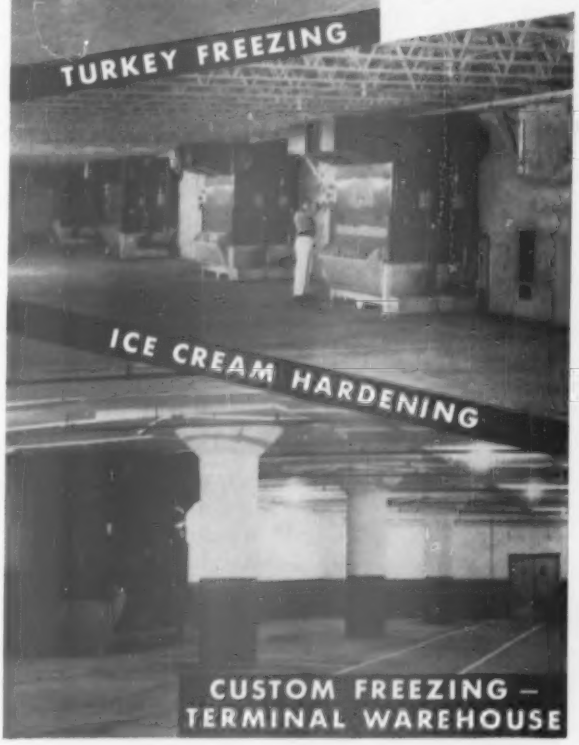

Write today for Bulletin No. 105, Address

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District Engineers in Principal Cities of United States and Canada

FOOD INDUSTRY TOPICS

An interesting write-up on the new 16 mm black-and-white sound film, "The Ultimate Structure," available for showings on loan or purchase at cost, and a visit to the Engineering Experiment Station and the Department of Chemistry, Physics, and Metallurgical Engineering of The Ohio State University are featured in the July-August issue of *Norelco Reporter*, published by North American Philips Co., Inc., Mount Vernon, N. Y.

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A tasteful article entitled "Pickles Come of Age," tracing the pedigree of this food item since Roman times, is the featured article of the *D&O News* for September 1955, published by Dodge & Olcott, Inc., 180 Varick St., New York 14, N. Y.

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Bulletin 113-HR, available from Aurora Pump Division, The New York Air Brake Co., Aurora, Ill., describes Aurora Type HR Apco-Matic Condensation Return Units for heating systems with E.D.R. ratings from 8000 to 10,000, and pressures up to 80 psi. Equipped with large, 25-gallon capacity receiver tanks, the HR units are intended for heavy-duty installations where additional condensate storage is desired. Write direct or c/o Gale Benn Associates, Lincoln Bldg., New York 17, N. Y.

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Pictured and described in Bulletin 55782, published by Bakery-Chemical Division, Read Standard Corp., York, Pa., are the firm's line of mixers, including spiral ribbon mixers, double-arm mixers of tilting-bowl, stationary-bowl, and vacuum types; planetary-action vertical mixers; and laboratory mixers of the overlapping-arm type. Sifters, storage bins, weigh hoppers, screw elevators, and screw conveyors are described also. Write the company or Adams Associates, Inc., 28 N. Queen St., York, Pa.

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A series of free charts showing the Variation of Load at Yield of Type 304 Stainless Steel Tubing when held by Crawford Swagelok Tube Fittings has been issued by Crawford Fitting Co., 884 E. 140th St., Cleveland 10, O. Complete and accurate test data are shown on ½", ¾", and 1" stainless steel tubing in various sizes of wall thicknesses, and in pressures at temperatures ranging from 72° F. to 1800° F. Comparisons also are shown with allowable loads calculated from S values as specified by A. S. T. M.

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According to the July-August issue of its *NEWS*, published by the National Agricultural Chemicals Assn., 1145 19th St., N. W., Washington, D. C., radioisotopes are expected to provide increasing assistance in pesticide research, both in such uses as the "tagging" of insects so as to determine their flight range, migrating routes and over-wintering habits, and in studies designed to determine the nature of insect resistance to poisons.

"The Story of the Ring-Jet Pump," a new 8-page booklet issued by F. J. Stokes Machine Co., Inc., 5500 Tabor Rd., Philadelphia 20, Pa., tells how the firm developed its new line of diffusion and booster pumps to fill the need for faster pumping in the pressure range where most high vacuum processing now is being done. Ask for Bulletin 756.

. . . *meeting hall and conference room*

Estimated attendance at the 1955 International Soft Drink Industry Exposition, to be held November 14-17 in Miami, is expected to approach the near-record of 9874 registered at last year's gathering in Philadelphia. On display will be new advancements in equipment and services designed to manufacture, distribute, and promote sale of soft drinks—including such items as materials handling machinery, bottle vending equipment, trucks and trailers, and sanitary products.

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Discussions covering the scope, development, and current trends of the institutional food market and supervisory personnel's role in the sales field are scheduled for the sales conference of the Institutional Food Manufacturers of America. The conference, to be held in cooperation with Michigan State University, is scheduled for January 6-7 at Kellogg Center, East Lansing, Mich.

. . . *building up and branching out*

Plans for one of the most advanced food research facilities in the world have been announced by H. J. Heinz Co. The $3,000,000 building (architect's sketch above) will be called the Heinz Research and Quality Control Center, and will house the international headquarters offices, a pilot plant, experimental kitchens, research laboratories, quality control units, and a research library. The structure will take its place among the Pittsburgh factory building group, on the city's North Side, with completion scheduled for early 1957.

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American Wheelabrator & Equipment Corp., Mishawaka, Ind., announces it has changed its corporate name to Wheelabrator Corp. The move does not involve any alteration in ownership, management, or operation of the firm, which manufactures blast cleaning, dust and fume control, and foundry equipment.

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Expansion of General Mills research facilities to a 104-acre campus-like setting on the outskirts of Minneapolis will begin in 1956. The firm's steadily grow-

ing work in food and chemical research, plus development of new food and industrial chemical products, has created a pressing need for more space. The present research staff consists of more than 300 men and women. The new Research Center, to consist of several buildings constructed over a 3- to 5-year period, will be located within 2 miles of the suburban site selected for a new General Mills general office building, scheduled for 1958 completion. The company's Mechanical Division will add the present laboratories to its own existing research facilities.

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Directors of General Foods have approved final building plans for a new food research center in Tarrytown, N. Y. The program provides for several 2-story buildings on the 55-acre site. The campus-type structures—to be ready for occupancy about mid-1957—will be air-conditioned and soundproofed, and will furnish working space for about 650 executives, research scientists, office personnel, and others. According to Mr. Charles G. Mortimer, company president, a principal reason for the expansion is General Foods' decision to devote important research funds to "pioneering research." In addition, the move will release the Central Laboratories space in Hoboken, N. J., and make it possible to turn over fully equipped divisional research units to the company's Maxwell House and Jell-O divisions.

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Ground-breaking for the new American Can Company plant at Arlington, Texas, finds Mr. C. E. McCloskey, manager of the new plant, examining a can, while Mr. T. J. Vandergriff, mayor of Arlington (left rear), and Mr. M. P. Cortilet, vice president of Canco's Central Division, break the ground. The factory will employ about 170 people, and will have an annual production capacity of 300,000,000 containers for fruit, vegetables, meat, and shortening. Production will start in 1956 to help meet the needs of Central Texas' expanding food packing industry. This will be Canco's second can-making plant in Texas.

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Dow Corning Corp., Midland, Mich., pioneer and leading producer of silicones, has been named winner of the 1955 Award for Chemical Engineering Achievement. Announcement was made by Dr. Sidney D. Kirkpatrick, editorial director of *Chemical Engineering*, McGraw-Hill publication which sponsors the award. The firm was chosen by an 84-man committee of chemical engineering educators headed by Prof. Walter G. Whitman, director of the chemical engi-

Eastman offers widest range of antioxidants

If your food product needs protection against rancidity, bad odor or off-flavor caused by oxidative deterioration, Eastman can help you.

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Animal Fats and Oils	Cosmetics
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Chewing Gum	Potato Chips
Meat Products	Dog Food
Crackers	Premixes
Paper Board	Spices
Dairy Products	Wax
Chicken Fat	Candy
Vegetable Fats and Oils	Nuts

Don't let rancidity cause returns, losses and dissatisfied customers. Look into the simple remedy of antioxidants. Their cost is low.

Eastman will be glad to recommend an antioxidant treatment or even undertake a testing program for whatever food product you wish to stabilize. The recommendations you receive will represent the most effective treatment at the lowest possible cost. For Eastman offers a full range of antioxidants and has no axe to grind in favor of any one antioxidant. We make them all!

For more information about Tenox, write to Eastman Chemical Products, Inc., Kingsport, Tennessee—a subsidiary of Eastman Kodak Company.

Tenox Eastman Food-grade Antioxidants

SALES OFFICES: Eastman Chemical Products, Inc., Kingsport, Tenn.; New York — 260 Madison Ave.; Framingham, Mass. — 65 Concord St.; Cincinnati — Carew Tower; Cleveland — Terminal Tower Bldg.; Chicago — 360 N. Michigan Ave.; St. Louis — Continental Bldg.; Houston — 412 Main St. **West Coast: Wilson Meyer Co.,** San Francisco — 333 Montgomery St.; Los Angeles — 4800 District Blvd.; Portland — 520 S. W. Sixth Ave.; Salt Lake City — 73 S. Main St.; Seattle — 821 Second Ave.; **Canada: P. N. Soden Co., Ltd.,** Montreal, Quebec — 2143 St. Patrick St.; Toronto, Ontario — 1498 Yonge St.

FOOD INDUSTRY TOPICS

neering department of MIT. Since 1933, a dozen companies—or industrial groups—have received this biennial award for successes in development, design, and operation of great plants and processes. In selecting Dow Corning, the committee for the first time honored a firm primarily for successful participation of its chemical engineers in commercial development of new products, markets, and sales. Also recognized were the contributions of Dow Corning's chemical engineers to silicone process research and development. Formal Award presentation will be made at a dinner in the Bellevue-Stratford Hotel, Philadelphia, December 7, in connection with the 25th biennial Exposition of the Chemical Industries.

. . . *the human element*

The Pfaudler Company, Rochester, N. Y., announces the following sales appointments: **Mr. Robert Scrimgeour** as its St. Louis district representative; **Mr. John S. Volpi** as district sales representative serving Kansas, Oklahoma, Nebraska, Colorado, and Northwest Missouri, operating from an office at 5200 W. 57th St., Mission, Kans.; and **Mr. Frederick G. Josenhans, Jr.,** as district sales representative for Eastern Pennsylvania, operating out of Pfaudler's Regional Office, 29 Bala Ave., Bala Cynwyd, Philadelphia, Pa.

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Dr. Robert M. Brick, former director of the school of metallurgical engineering, University of Pennsylvania, has been named director of the department of metallurgy of Continental Can Company's Research and Engineering Division, according to announcement by Mr. Curtis E. Maier, general manager of the division. Dr. Brick is a consultant to the U. S. Army's Frankford Arsenal and to the Atomic Energy Commission's installations. He is a former consultant to the Oak Ridge National Laboratory. His industrial experience included employment by the Aluminum Company of America, Bethlehem Steel, and consulting work. His academic career has included membership on the faculty of Yale University. He also is author of a widely-used college textbook on metallurgy and over 30 scientific papers.

. . . Metallurgist Brick of CCC

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Dr. Earl Auerbach, assistant histochemist on the research staff of the American Meat Institute Foundation, has been appointed administrative assistant to Dr. H. R. Kraybill, Foundation vice president and director of research and education. The Foundation is a not-for-profit organization located at and affiliated with The University of Chicago. It recently announced launching of a comprehensive program of scientific research, designed to develop improved processing methods and to create new uses for cattle hides.

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Mr. Kenneth W. Tracy, veteran of over 40 years affiliation with the perfume, cosmetic, and pharmaceutical trades, and with Fritzsche Brothers, Inc., New York City, since 1941, will retire as of December 31, 1955. **Mr. Warren R. Godfrey,** for 20 years manager of the firm's Philadelphia office, has been transferred to the home office at New York to succeed Mr. Tracy as director of Perfume Sales. Closely cooperating with Mr. Godfrey, **Mr. Ernest A. Lawson** will continue to direct Fritzsche Brothers' expanding Industrial Odorant Division, in which field he has specialized for 18 years.

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. . . Staffmen Eaton . . . and Flavin . . . and Jobe

Johns-Manville will split its present Industrial Products Division into 3 new operating divisions, the Industrial Insulations Division, the Packings and Friction Materials Division, and the Pipe Division. General manager of the new Industrial Insulations Division will be **Mr. Don L. Hinmon,** who also has been elected vice president of Johns-Manville Sales Corp., it was announced by Mr. A. R. Fisher, president of Johns-Manville Corp. Mr. Hinmon's staff will include **Mr. Thomas H. Eaton,** production manager, who has been elected vice president of Johns-Manville Products Corp., and **Mr. J. B. Jobe,** merchandise manager, and **Mr. Edward D. Flavin,** general sales manager, who have been elected vice presidents of Johns-Manville Sales Corp. Other new Division general managers named are **Francis J. Waken,** Packings and Friction Materials Division, and **Mr. Robert F. Orth,** Pipe Division.

. . . and General Manager Hinmon of J-M'S Industrial Division

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Mr. H. C. ("Dutch") Diehl, director of the Refrigeration Research Foundation, 200 Midland Bldg., Colorado Springs, Colo., recently represented his organization at the 9th International Congress of Refrigeration, held in Paris, August 31 - September 16. He served also as delegate of the American Society of Refrigerating Engineers, and as unofficial and

friendly observer of the Congress for the American Institute of Refrigeration.

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. . . MSG and HVP for Huron's O'Neill

Appointment of **Mr. James O'Neill** as a sales representative for Huron Milling Company, 9 Park Place, New York City, was announced by Mr. Glenn H. Freeman, director of sales, Specialty Products. Mr. O'Neill will cover the New York metropolitan area on Huron's flavor enhancing food additives—Huron MSG (monosodium glutamate), and Huron HVP (hydrolized vegetable protein).

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At a meeting of the board of directors of Cochran Foil Co., 1430 S. 13th St., Louisville 1, Ky., **Mr. H. G. Hanks,** a vice president and director of the firm, was made director of sales. **Mr. T. D. Gebhart,** also a vice president and director, was made director of manufacturing. **Mr. C. W. Huflage,** vice president, who also has been sales manager of the Laminating Division, was named general sales manager of the company. Mr. Archie P. Cochran, president, stated the new positions were necessary due to expanded sales activity and to the integration of the sales of the firm's Rolling Division, Laminating Division, and Products Division.

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Appointment of **Mr. Donald L. Schott** as technical application engineer was made recently by the Eastern Operation of Food Machinery and Chemical Corporation's Canning Machinery Division at Hoopeston, Ill. Mr. Schott, formerly with Chain Belt Co., Milwaukee, became associated with FMC when it acquired Chain Belt's line of canning machinery equipment. He will deal primarily with applications of FMC's Micro-Film Deaerator, Roto-Brush Can Cleaner, Agi-Tort Sterilizer, and the Sterilmatic Continuous Pressure Cooker and Cooler.

. . . a Schott for FMC

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Mr. Edward Van Allsburn of New York City has been retained by A. E. Staley Mfg. Co., Decatur, Ill., corn and soybean processor, to give special technical assistance to its food customers in the Philadelphia,

Here's a good man to know— an expert on saving money

This is your Koppers salesman. He can show you how to save money through the use of ***dbpc*** food grade antioxidant—Koppers' economical inhibitor that protects foods against deterioration for slightly more than one cent per 100 pounds.

He'll show you, too, how you can formulate your own antioxidant solutions with white, free-flowing ***dbpc*** crystals—highly soluble in animal and vegetable oils. Furthermore, ***dbpc*** possesses good stability, is convenient to handle, and does not impart color, odor or flavor to foods.

It will be worth your while to find out how an extremely small amount of ***dbpc***—as little as 1 part in 10,000—added to the product at the time of processing can effectively inhibit deterioration, reduce waste and save you money. For complete information, write to Koppers Company, Inc., Chemical Division, Dept. FT-115, Pittsburgh 19, Pennsylvania.

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Koppers Chemicals

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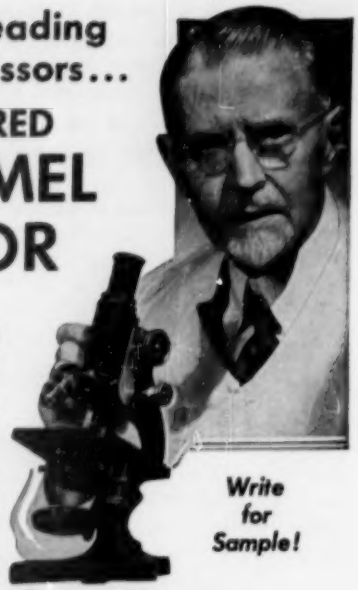

A dehydrated food color, made entirely from dextrose sugar by cooking under controlled conditions.

It has particular use in dry food products where the use calls for a natural color ranging from a light to a very dark brown. For example:

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Powdered Desserts *Dehydrated Soups*
Dry Cake Mixes *Bouillon Powders*
Powdered Coffee & other beverages
Powdered Gravy Seasonings

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FOOD INDUSTRY TOPICS

New York, and New England territories. He was formerly editor of *Biscuit & Cracker Baker*, and with the technical department of the Independent Biscuit Mnaufacturers. He also has had charge of technical departments of biscuit and candy plants.

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. . . Cyanamid's Clark

American Cyanamid Co., Fine Chemicals Division, 30 Rockefeller Plaza, New York 20, N. Y., has announced appointment of **Mr. Hamilton E. Clark** as western regional sales manager. Mr. Clark, whose offices will be in Los Angeles, will direct the sales activities of the animal feed, pharmaceutical, and food industry departments. He was previously sales manager of the animal feed department of the Fine Chemicals Division.

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Appointment of **Mr. Kenneth L. Behneman** as chief engineer was announced by Mr. Walter Krenz, president of Oscar Krenz, Inc., Ashby at Sixth St., Berkeley 10, Calif., manufacturers of alloy code vessels for chemical and petroleum plants, and processing equipment for the food, wine, and brewery industries.

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Mrs. Ann Williams-Heller, internationally known home economist, has been named food and equipment editor of *Everywoman's Magazine*, according to announcement by Mr. J. Walter Flynn, editor. Mrs. Williams-Heller has authored 5 popular cookbooks and over 150 published feature articles. Her professional activities in this country have included coast-to-coast lecture tours before women's and professional groups, radio and TV interviews, and judging in national cooking and recipe contests. In Europe, she held important nutrition posts in hospitals, hotels, and restaurants in Vienna and Zurich. She also organized a special Food and Nutrition Section for the Austrian Department of Agriculture, and was for a time director of the London College of Dietetics.

. . . Everywoman's Mrs. Williams-Heller

◆ ◆ ◆

Mr. Wm. J. Hoelle, assistant West Coast division sales manager for Minute Maid, has been promoted to chain store sales manager for Hi-C products, it was announced by Mr. Niles Foster, general manager of the Hi-C division, Minute Maid - Snow Crop Frozen Foods. Mr. Hoelle has been with Minute Maid since 1949.

◆ ◆ ◆

Mr. Adolph Dingfelder, until recently an executive in the export department of Felton Chemical Co., Inc., 599 Johnson Ave., Brooklyn 37, N. Y., has been named sales manager of the flavor firm. Felton also announces expansion of its distribution facilities in Mexico with a move into new and larger quarters in Mexico City at Bahia de Todos Los Santos No. 174-A. **Mr. Juan Arenas Robledo** is manager of Felcomex, S. A., Felton's Mexican operation, and **Dr. Oscar L. Urrutia** is manager of the company's Latin American Division.

. . . Dingfelder moves up at Felton

◆ ◆ ◆

Mr. Richard S. Perkin, president and chairman of the board of The Perkin-Elmer Corp., Norwalk, Conn., has been elected a Fellow of the American Academy of Arts and Sciences. The honor was accorded in recognition of his accomplishments in the field of Administration and Affairs.

◆ ◆ ◆

National Dairy Research Laboratories, Inc., Oakdale, Long Island, N. Y., announces appointment of

Mr. Chas. R. Tobin to the staff of the Engineering Department, Dairy Products Laboratory.

◆ ◆ ◆

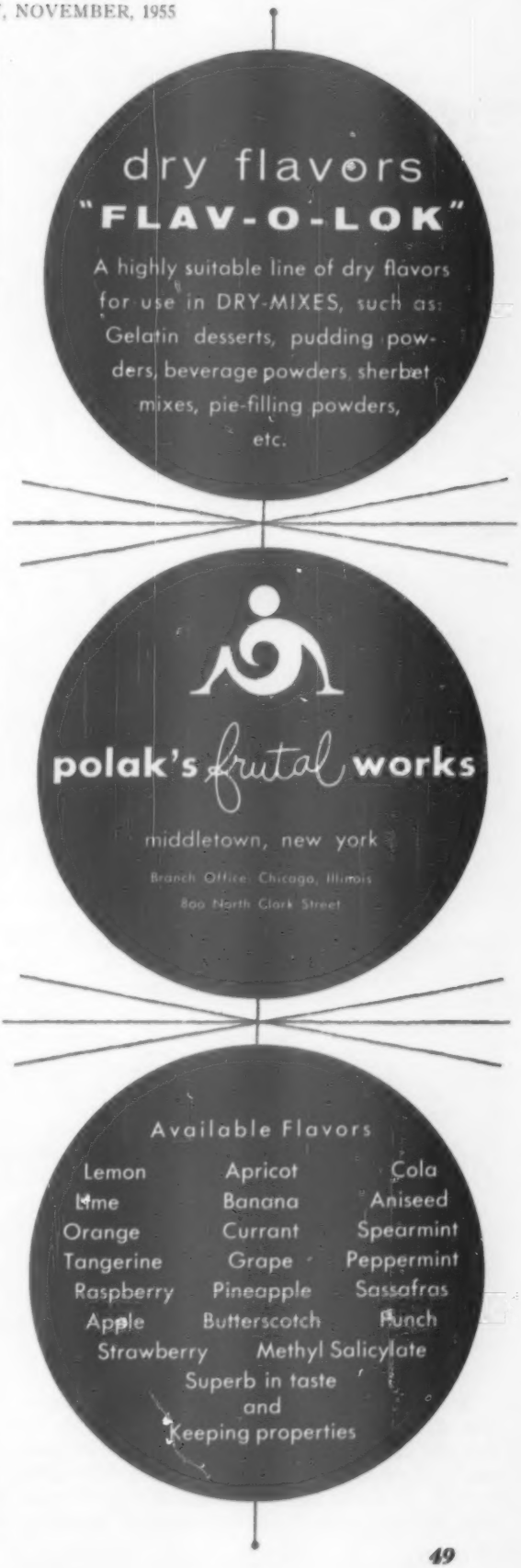
Dr. Harold Vagtborg, president of Southwest Research Institute, 8500 Culebra Rd., San Antonio, Texas, has announced appointment of **Mr. S. H. Simpson, Jr.,** former manager of Institute communications research, as assistant vice president concentrating on coordination of the Institute's broad research program for industry, business, and the military services. Mr. Simpson, a specialist in commercial and military communications research and in engineering administration, was assistant vice president with RCA Communications, Inc., before coming to the Institute in 1953, and previously directed the worldwide communications activities of the OSS during World War II. Dr. Vagtborg also announced creation of a new Electrical Engineering Department, which will assume responsibility for certain research areas formerly included within the research organization's Physics Department. Chairman of the new Institute department is **Mr. Wm. A. Mussen.**

◆ ◆ ◆

Oakite Products, Inc., 19 Rector St., New York City, manufacturers of specialized industrial cleaning and related materials, announces appointment of 3 new technical service representatives. **Mr. John A. Price** has been assigned to serve food industry accounts in the West Chicago area. **Mr. John C. Mullarkey** has been assigned to the Phoenix, Ariz., terri-

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

1955	
October 31-November 2	Seventeenth Annual Forum of the Packaging Institute, Hotel Statler, New York
November 14 and 15	Technical Association of the Pulp and Paper Industry National Plastics Meeting, Brooklyn Law School, 375 Pearl Street, Brooklyn, New York
November 16, 17, 18	National Convention of the Association of Food Industry Sanitarians, Hotel El Rancho, Sacramento, California
1956	
January 12-14	Conference on the Use of Isotopes in Agriculture, Council of Participating Institutions of Argonne National Laboratory, Michigan State University, East Lansing, Michigan
February 6-17	Ice Cream Short Course, North Carolina State College, Raleigh, North Carolina
March 13 and 14	Fourth Annual National Dairy Engineering Conference, Kellogg Center, Michigan State University, East Lansing, Michigan
March 15 and 16	First International Symposium on Physics in the Food Industry, Plaza Hotel, San Antonio, Texas
April 8-13	One hundred and twenty-ninth National Meeting of the American Chemical Society, Dallas, Texas
June 10-14	**Sixteenth Annual Meeting of the Institute of Food Technologists, Hotel Jefferson, St. Louis, Missouri**



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FOOD INDUSTRY TOPICS

tory. **Mr. Chas. L. Blasingame** is now servicing Oakite accounts in Dayton, O.

◆ ◆ ◆

. . . Frost-O-Fast's Sandy Werbin

Mr. Sanford (Sandy) Werbin has joined Basic Foods Sales Corp., Bancker St., Englewood, N. J., as director of research of the company's Frost-O-Fast Division, it was announced by Mr. Gerard Weinstock, president. IFT member Werbin, who has been chief food chemist at Stein, Hall and Co., Inc., for the past 19 years, holds patents on 4 food processing inventions, and has published numerous articles and lectured at leading universities. He holds membership in American Society of Bakery Engineers, American Association of Cereal Chemists, and the American Dairy Science Association.

◆ ◆ ◆

The retirement of **Mr. A. von Gontard** as vice chairman of the board of Anheuser-Busch, Inc., St. Louis, Mo., and chairman of the brewery's executive committee, was announced on October 1. Born in Germany in 1900, he began his career with Anheuser-Busch in 1923, when he was appointed assistant technical director of the brewery after graduating from the Institute of Technology at Karlsruhe, Baden. Mr. von Gontard will remain a member of the board of directors of the brewery. He intends to spend considerable time devoting himself to civic interests.

● *Unsolved Problems in Food and Nutrition Research*

Developmental Research

Objective methods for determining more accurately the extent of color, flavor, and texture changes in frozen and canned fish.

The chemical composition of elements of color and flavor in foods and how these change with processing.

Development of methods for reducing the moisture content of orange juice to the lowest possible level (below .5%).

Fundamental investigations of the chemistry of flavor changes in citrus products.

Ways to improve the palatability and use of milk concentrate.

Improvement in stability and reconstitutability of dried egg.

Ways to improve the palatability of low sodium diets.

A physico-chemical study of factors affecting cloud in citrus juices and beverages—particle size, charge distribution, viscosity, etc.

Improved methods for maintaining quality of foods during manufacture and distribution.

Development of an efficient, low cost method of fish reduction practical for use in conjunction with individual processing plants.

Proper processing of oil seed meals.

The inherent factors, such as enzyme systems and pH of foods, which determine stability of vitamins.

The stabilization of folic acid in solutions containing riboflavin.

Source of, control of, and disposal of odors created in the food industry.

Development of simplified objective methods for use in field quality control for determination of fish freshness.

Excerpted from the Survey of Food and Nutrition Research in the U. S. A., 1952-53, Food and Nutrition Board, National Research Council.

Processing and Storage Problems
Chemical Additives

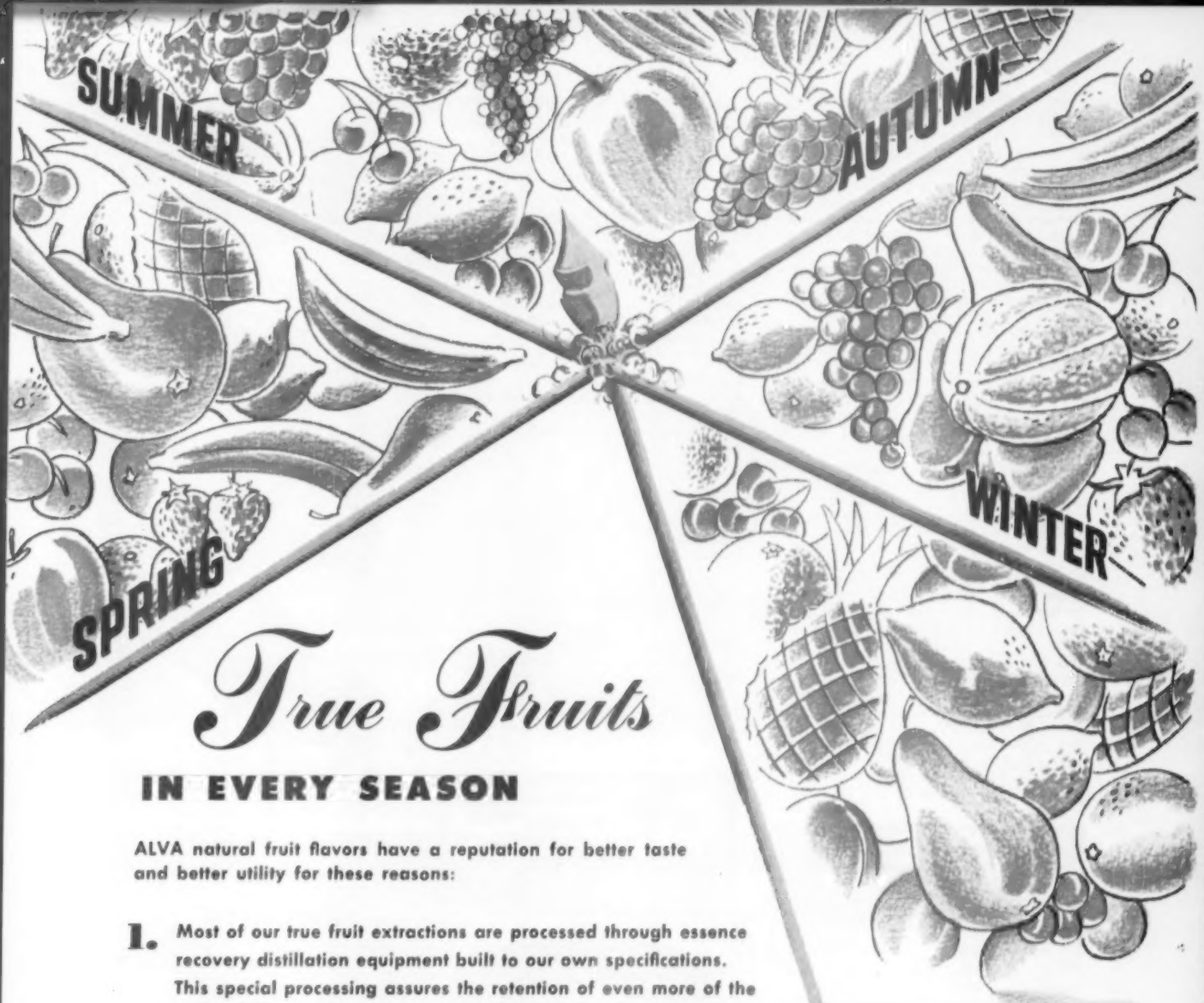
Phosphate in applied usages, as acidulants, humectants, emulsifiers, neutralizers, etc., in food processing or as additives, and the effect on nutritional availability and utilization of the food.

A commercial use for a mixture of leucine and isoleucine, which would have large outlets in some technical field.

Production of emulsifiers and stabilizers nontoxic to the human body but able to operate so as to stabilize water-fat emulsions for long periods under favorable conditions of temperature, mechanical vibration, etc.

Safety of surface-active agents for use in foods.

Excerpted from the Survey of Food and Nutrition Research in the U. S. A., 1952-53, Food and Nutrition Board, National Research Council.



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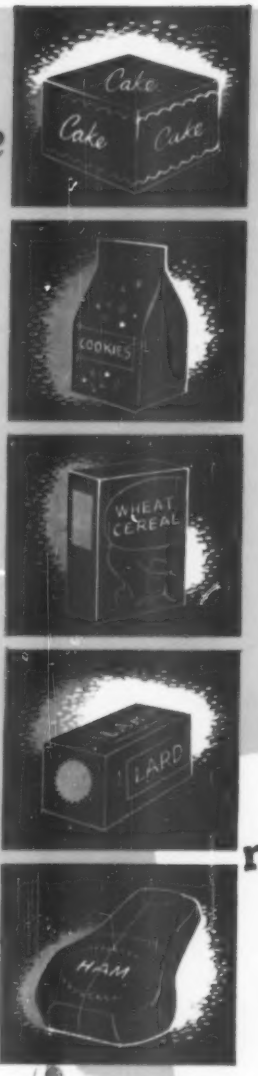

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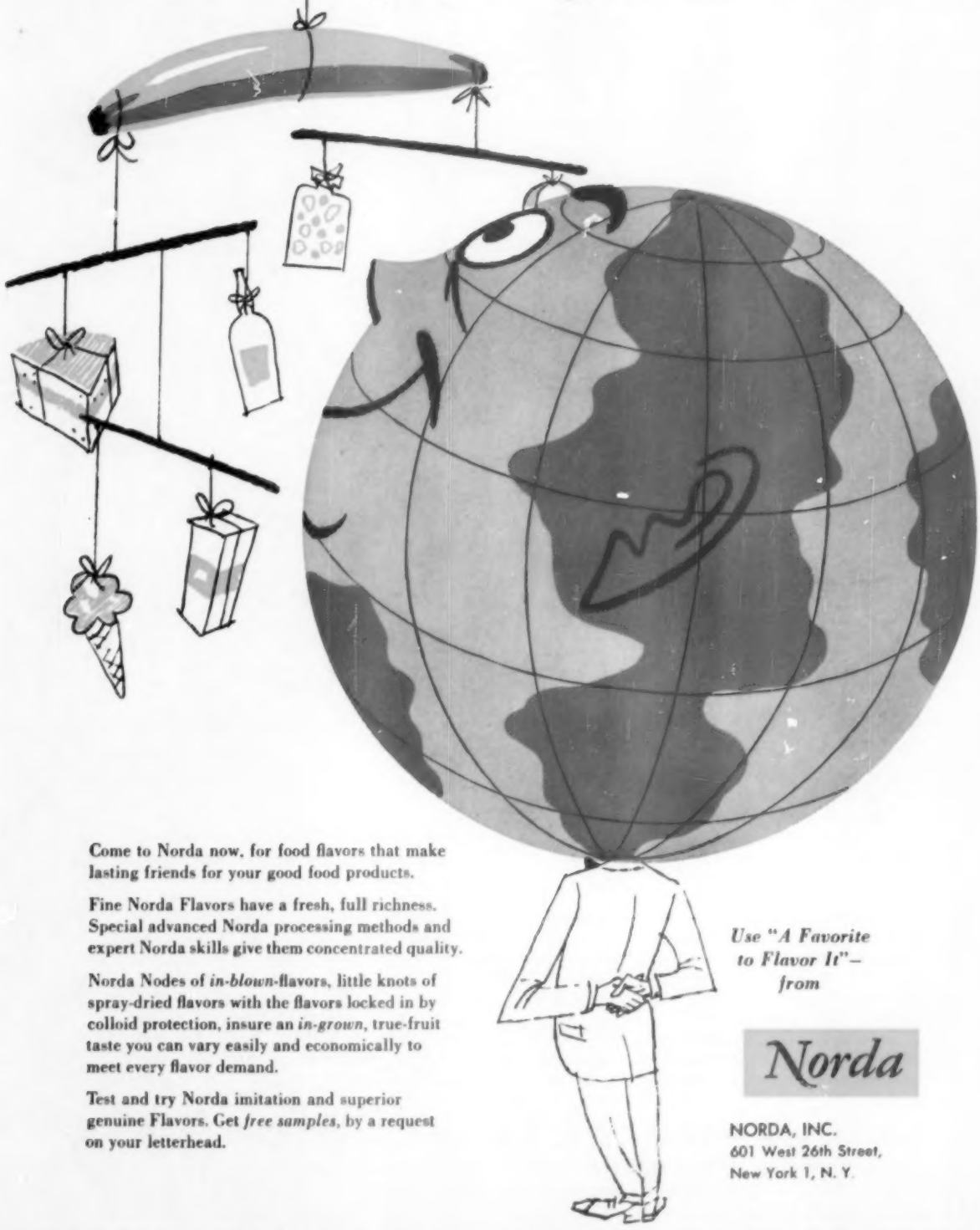

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